DOCUMENT RESUME

ED 419 923 CE 076 530

AUTHOR	Nevils, Aaron
TITLE	Biotechnology: Applications in Agriculture. Instructor Guide [and] Student Reference.
INSTITUTION	Missouri Univ., Columbia. Instructional Materials Lab.
SPONS AGENCY	Missouri State Dept. of Elementary and Secondary Education, Jefferson City. Div. of Vocational and Adult Education.
PUB DATE	1998-03-00
NOTE	265p.
AVAILABLE FROM	Instructional Materials Laboratory, University of Missouri, 2316 Industrial Drive, Columbia, MO 65202; toll-free phone: 800-669-2465; http://iml.coe.missouri.edu (order no. 10-1029-I, instructor guide: $25; 10-1029-S, student reference: $4).
PUB TYPE	Guides - Classroom - Learner (051) -- Guides - Classroom - Teacher (052)
EDRS PRICE	EDRS Price MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Agricultural Education; *Agricultural Production; *Agronomy; *Animal Husbandry; *Biotechnology; *Genetic Engineering; Instructional Materials; Learning Activities; Lesson Plans; Postsecondary Education; Secondary Education; State Curriculum Guides; Teaching Guides; Technological Advancement
IDENTIFIERS	Missouri

ABSTRACT

This curriculum guide incorporates the needed components to aid agriculture teachers in the implementation of the Vocational Instructional Management System in biotechnology: applications in agriculture. The guide begins with a list of the competencies/objectives found in the six units; list of references and materials; list of materials and equipment required for activities; list of supply companies; teaching calendar; and competency profile. The curriculum contains six units, each consisting of one to five lessons. Components of each lesson may include the following: an introductory page with lesson title, competency/objective, study questions, and references; transparency masters and activity sheet(s); teaching procedures; motivational techniques; other activities; evaluations; answers to evaluations and activity sheets; references and teaching aids; and materials and equipment. Unit topics include the following: introduction to biotechnology; issues in biotechnology; basic laboratory skills; foundations of genetic engineering; animal technologies; and plant technologies. The student reference contains informational readings for each lesson and a glossary. (YLB)

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Biotechnology: Applications in Agriculture
Instructor Guide
Student Reference

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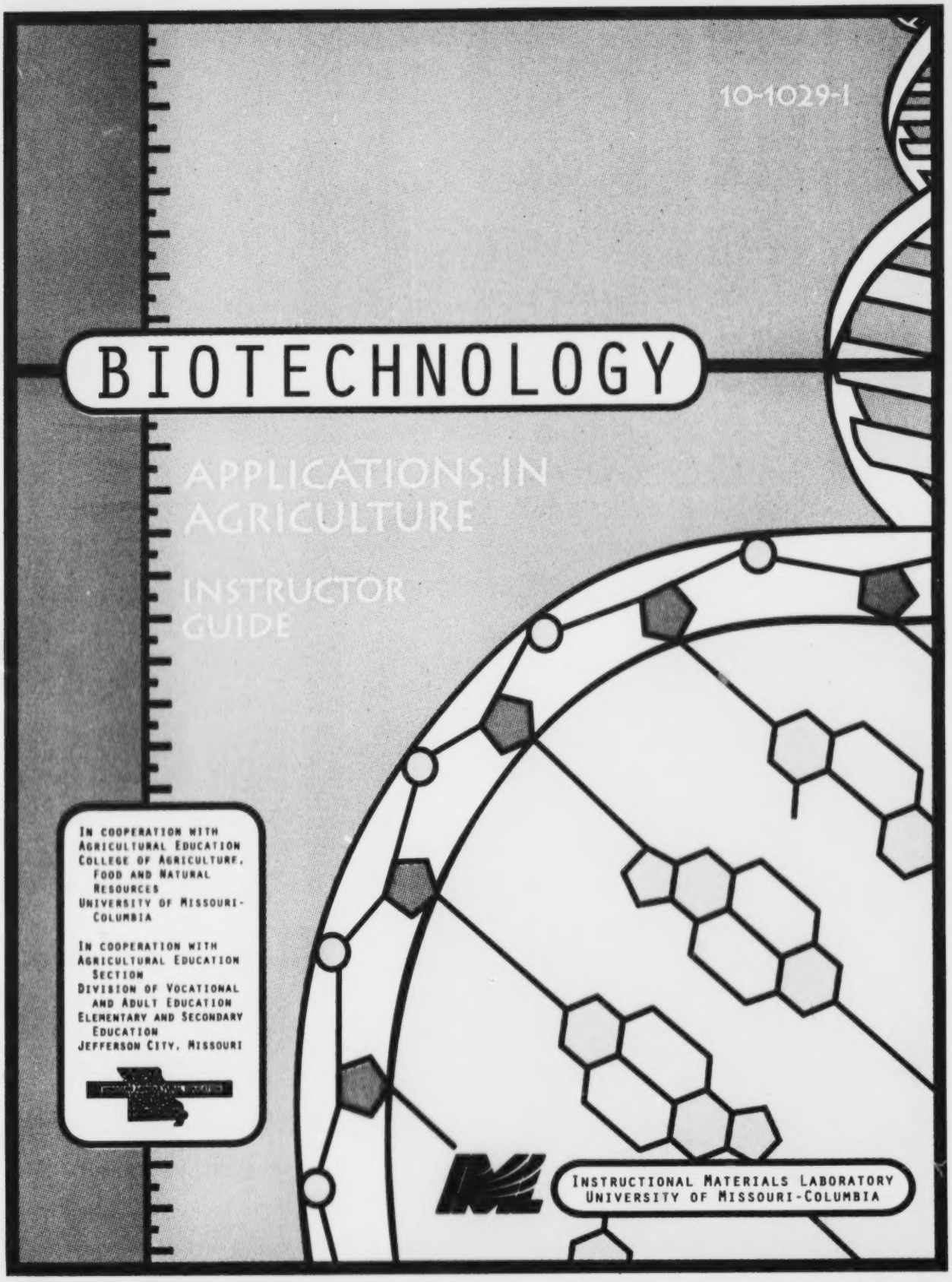
10-1029-1
BIOTECHNOLOGY
APPLICATIONS IN AGRICULTURE
INSTRUCTOR GUIDE
IN COOPERATION WITH
AGRICULTURAL EDUCATION
COLLEGE OF AGRICULTURE, FOOD AND NATURAL RESOURCES
UNIVERSITY OF MISSOURI-COLUMBIA
IN COOPERATION WITH
AGRICULTURAL EDUCATION SECTION
DIVISION OF VOCATIONAL AND ADULT EDUCATION
ELEMENTARY AND SECONDARY EDUCATION
JEFFERSON CITY, MISSOURI
INSTRUCTIONAL MATERIALS LABORATORY
UNIVERSITY OF MISSOURI-COLUMBIA

Instructor Guide

BIOTECHNOLOGY: APPLICATIONS IN AGRICULTURE

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Produced by:
Instructional Materials Laboratory
University of Missouri-Columbia
10 London Hall
Columbia, Missouri 65211

Volume 30
Number 9

Catalog Number 10-1029-I
March 1998

Available from:
Instructional Materials Laboratory
University of Missouri-Columbia
10 London Hall
Columbia, MO 65211
573-882-2883

The activity that is the subject of this report was supported in whole or in part by funds from the Department of Elementary and Secondary Education, Division of Vocational and Adult Education. However, the opinions expressed herein do not necessarily reflect the position or policies of the Missouri Department of Elementary and Secondary Education or the Division of Vocational and Adult Education, and no official endorsement should be inferred.

ACKNOWLEDGMENTS

Recognition is given to the following advisory committee members for providing their valuable time and suggestions in developing this curriculum. The committee consisted of Jeff Kitchen, Jim Welker, Bob Birkenholz, Kristen Kingsland, Marvin Hoskey, Richard Norris, Corey Mouser, Chris Stockhorst, Phil Fox, Richard Asbill, Aaron Nevils, and Delbert Lund.

Appreciation is expressed to the following staff members of the Instructional Materials Laboratory for their efforts in producing this material: Phyllis Miller, Interim Director; Dan Stapleton, Assistant Director; Eileen Woody, Assistant Director; Veronica Feilner, Senior Editor; Kevin Gamble, Graphic Artist; Jan Trimble, Word Processor; and Jill Clark and Shelly Seabaugh, Editorial Assistants.

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FOREWORD

The development of the *Biotechnology: Applications in Agriculture* curriculum guide is the result of suggestions by the MVATA Teaching Aids Committee. The Biotechnology Advisory Committee suggested the topics to be included and reviewed the materials.

This curriculum contains six units. The instructor guide includes objectives, competencies, motivational techniques, teaching procedures, other activities, activity sheets, transparency masters, evaluations, answers to evaluations and activity sheets, references and teaching aids, and materials and equipment. Topics include an introduction to biotechnology, issues in biotechnology, basic laboratory skills, foundations of genetic engineering, animal technologies, and plant technologies. One copy of the student reference is packaged with the instructor guide. Additional copies of the student reference can be purchased separately.

During the summer of 1981, the Missouri State Board of Education formally adopted the concept of "Instructional Management Systems" (IMS) as a priority for the 1981-82 school year. The Missouri Commissioner of Education described the IMS concept as a practical way of "organizing for excellence" in education. To meet the demand for greater productivity and accountability, the director of Vocational Education applied the elements of IMS to form the Vocational Instructional Management System (VIMS). The VIMS process provides a framework to use in planning and organizing to assure excellence in Missouri's vocational education system by focusing greater attention on the management of teaching and learning.

This guide incorporates the needed components to aid agriculture teachers in the implementation of VIMS. For ease of use, competencies/objectives have been included at the beginning of the guide as well as incorporated within each lesson. A competency profile has been provided in the front of the guide for convenient record keeping.

Robert J. Birkenholz, Program Leader and Professor
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BIOTECHNOLOGY: APPLICATIONS IN AGRICULTURE

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COMPETENCIES/OBJECTIVES

UNIT I--INTRODUCTION TO BIOTECHNOLOGY
1. Summarize the importance of biotechnology to agriculture.

UNIT II--ISSUES IN BIOTECHNOLOGY
1. Explain the major issues associated with agricultural biotechnology.
2. Identify government agencies involved in biotechnology.
3. Identify procedures involved in obtaining a patent for a biotechnology product.

UNIT III--BASIC LABORATORY SKILLS
1. Describe the steps in the scientific method.
2. Demonstrate the proper use of laboratory equipment and techniques.
3. Explain why safety practices should be followed in the laboratory.

UNIT IV--FOUNDATIONS OF GENETIC ENGINEERING
1. Identify the parts of a cell, including DNA, and their functions.
2. Explain how cells reproduce.
3. Describe the processes of genetic modification.

UNIT V--ANIMAL TECHNOLOGIES
1. Describe the process of artificial insemination.
2. Describe the process of embryo transfer.
3. Identify other applications of biotechnology in animals.
4. Summarize the impact of biotechnology on animal agriculture.

UNIT VI--PLANT TECHNOLOGIES

1. Describe traditional plant breeding processes.
2. Explain the process of tissue culture.
3. Describe current applications of biotechnology in plants.
4. Identify emerging applications of biotechnology in plants.
5. Summarize the impact of biotechnology on plant agriculture.

EVALUATION

1. Give short, objective tests following each lesson and a more in-depth objective test at the conclusion of the unit.

2. Observe the changes in behavior as evidence of the improved ability of students to deal with problems in this unit using backgound information acquired from earlier units.

3. Observe students' attempts to solve similar problems in their supervised agricultural experience programs.

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P.O. Box 7
Cedar Falls, IA 50613

2) *Ag Consultant*
Meister Publishing Company
37733 Euclid Avenue
Willoughby, OH 44094

3) *Agricultural Research*
Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402

4) *Biotechnology Notes*
USDA/OAB
Administration Building, Room 321-A
14th and Independence Avenue Southwest
Washington, D.C. 20250

5) *Science of Food and Agriculture*
Council for Agricultural Science and Technology
137 Lynn Avenue
Ames, IA 50010

MATERIALS AND EQUIPMENT REQUIRED FOR ACTIVITIES

1. Unit 3, Lesson 1: Using the Scientific Method

Petri dishes or test tubes purchased with sterile culture media
Sterile cotton swabs or balls
Pairs of sterile latex gloves or regular latex gloves dipped in alcohol and allowed to dry
Strips of Parafilm™ or clear tape
Strips of sterile first aid gauze
10 percent bleach solution
Ultraviolet light

2. Unit 4, Lesson 1: Comparing Plant and Animal Cells:

   Microscope
   Glass slides
   Cover slips
   Onion
   Toothpicks
   0.9 percent NaCl
   Methylene blue

3. Unit 4, Lesson 3: DNA Extraction

   Hot water bath or hot plate
   Candy or laboratory thermometer (to regulate the hot water bath)
   Cold water bath (ice water in a large bowl)
   Glass or plastic graduated cylinder (100 ml)
   Plastic teaspoon
   Pyrex glass or heat-resistant plastic beaker or flask (500 ml or larger)
   Piece of glass tubing bent to a 90 degree angle at the end
   Funnel or strainer with a coffee filter
   Flat toothpicks
   Medicine dropper or pipette
   Liquid soap (Woolite, laundry soap, or dish soap)
   Test tube for each student
   Medium onion, chopped
   Refrigerated alcohol
   Meat tenderizer

4. Unit 5, Lesson 1: Evaluating Semen

   Microscope with a 100x oil immersion objective
   Small amount of immersion oil
   Hot water bath (at approximately 98°F)
   Several glass test tubes
   Microscope slides and cover slips
   Frozen semen samples
   Semen stain (Blom's Esin-Nigrosin stain)
   Several eye droppers

5. Unit 5, Lesson 2: Examining Embryos

   Microscope (magnifying **less** than 100x, preferably 10x and 50x)
   Petri dishes (preferably gridded dishes)
   Embryo-holding media or flushing fluid
   Liquid nitrogen tank

6. Unit 6, Lesson 2: Tissue Culturing Strawberries

   Medium-sized stainless steel pan
   Long-handled spoon
   Glass test tubes with caps (25 x 100 mm size)
   Test tube racks
   Sterile distilled bottled water
   Glass (Pyrex) quart pitcher or old coffee pot
   Pressure cooker
   Eight-inch forceps

Sharp knife or scalpel
Parafilm™ or clear tape
Rubber or latex gloves
1 N NaOH
1 N HCl
Eyedroppers
Plastic graduated cylinder
Small bottle of household bleach
Premixed powder tissue culture medium (shoot multiplication media and pretransplant media)
Agar
Litmus paper (3.5-6.8) or a pH meter
Medium-sized plastic containers
Sterile paper towels
72-hole seedling tray (11 x 22)
Shelves lighted by cool white fluorescent lights
Transfer chamber
Strawberry runner tips (about 1 inch long)

7. Instructors may want to acquire some additional equipment to perform other activities not included in this curriculum, such as a micropipettor or electrophoresis apparatus (with power pack).

SUPPLY COMPANIES

1. Carolina Biological Supply Company
   2700 York Road
   Burlington, NC 27215
   1-800-334-5551
   In addition to laboratory supplies, Carolina Biological offers kits for various activities in biotechnology, including restriction analysis, gene-splicing, and DNA fingerprinting.

2. Edvotek Inc.
   14676 Rothgeb Drive
   Rockville, MD 20850
   1-800-338-6835

3. Modern Biology Inc.
   111 North 500 West
   West Lafayette, IN 47906
   1-800-733-6544

4. NASCO
   901 Janesville Avenue
   P.O. Box 901
   Fort Atkinson, WI 53538
   1-800-733-6544

Biotechnology: Applications in Agriculture

TEACHING CALENDAR

	Periods for Classroom Instruction/Activities	Length for Activity Sheets (AS)
Unit I, Lesson 1	3	AS 1.1 30 min.
Unit II, Lesson 1	5	AS 1.1 1 class period
Unit II, Lesson 2	4	AS 2.1 35 min.
Unit II, Lesson 3	6	AS 3.1 2 class periods
Unit III, Lesson 1	3	AS 1.1 45 min.
Unit III, Lesson 2	2	AS 2.1 15 min.
Unit III, Lesson 3	3	AS 3.1 40 min.
Unit IV, Lesson 1	3	AS 1.1 1 class period
Unit IV, Lesson 2	4	AS 2.1 1 class period
Unit IV, Lesson 3	7	AS 3.1 2 class periods
Unit V, Lesson 1	3	AS 1.1 1 class period
Unit V, Lesson 2	8	AS 2.1 1 class period
Unit V, Lesson 3	4	AS 3.1 1 class period
Unit V, Lesson 4	3	AS 4.1 30 min.
Unit VI, Lesson 1	3	AS 1.1 45 min.
Unit VI, Lesson 2	10	AS 2.1 3 class periods
Unit VI, Lesson 3	4	AS 3.1 35 min.
Unit VI, Lesson 4	4	AS 4.1 1 class period
Unit VI, Lesson 5	3	AS 5.1 30 min.

BIOTECHNOLOGY: APPLICATIONS IN AGRICULTURE
Competency Profile

Directions: Evaluate the student by checking the appropriate number or letter to indicate the degree of competency. The rating for each task should reflect **employability readiness** rather than the grades given in class.

Rating Scale:
3 Mastered - can work independently with no supervision
2 Requires Supe: vision - can perform job completely with limited supervision
1 Not Mastered - requires instruction and close supervision
N No Exposure - no experience or knowledge in this area

3	2	1	N

A. Introduction to Biotechnology

1. Summarize the importance of biotechnology to agriculture.

Other: _____

_____

3	2	1	N

B. Issues in Biotechnology

1. Explain the major issues associated with agricultural biotechnology.
2. Identify government agencies involved in biotechnology.
3. Identifify procedures involved in obtaining a patent for a biotechnology product.

Other: _____

_____

3	2	1	N

C. Basic Laboratory Skills

1. Describe the steps in the scientific method.
2. Demonstrate the proper use of laboratory equipment and techniques.
3. Explain why safety practices should be followed in the laboratory.

Other: _____

_____

3	2	1	N

D. Foundations of Genetic Engineering

1. Identify the parts of a cell, including DNA, and their functions.
2. Explain how cells reproduce.
3. Describe the processes of genetic modification.

Other: _____

_____

3	2	1	N

E. Animal Technologies

1. Describe the process of artificial insemination.
2. Describe the process of embryo transfer.
3. Identify other applications of biotechnology in animals.
4. Summarize the impact of biotechnology on animal agriculture.

Other: _____

_____

3	2	1	N

F. Plant Technologies

1. Describe traditional plant breeding processes.
2. Explain the process of tissue culture.
3. Describe current applications of biotechnology in plants.
4. Identify emerging applications of biotechnology in plants.
5. Summarize the impact of biotechnology on plant agriculture.

Other: _____

_____

Biotechnology: Applications in Agriculture

Student Names														

UNIT I - INTRODUCTION TO BIOTECHNOLOGY

1. Summarize the importance of biotechnology to agriculture.

UNIT II - ISSUES IN BIOTECHNOLOGY

1. Explain the major issues associated with agricultural biotechnology.
2. Identify government agencies involved in biotechnology.
3. Identify procedures involved in obtaining a patent for a biotechnology product.

UNIT III - BASIC LABORATORY SKILLS

1. Describe the steps in the scientific method.
2. Demonstrate the proper use of laboratory equipment and techniques.
3. Explain why safety practices should be followed in the laboratory.

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

1. Identify the parts of a cell, including DNA, and their functions.
2. Explain how cells reproduce.
3. Describe the processes of genetic modification.

UNIT V - ANIMAL TECHNOLOGIES

1. Describe the process of artificial insemination.
2. Describe the process of embryo transfer.
3. Identify other applications of biotechnology in animals.
4. Summarize the impact of biotechnology in animal agriculture.

Student Names															

UNIT VI - PLANT TECHNOLOGIES

1. Describe traditional plant breeding processes.
2. Explain the process of tissue culture.
3. Describe current applications of biotechnology in plants.
4. Identify emerging applications of biotechnology in plants.
5. Summarize the impact of biotechnology in plant agriculture.

UNIT I - INTRODUCTION TO BIOTECHNOLOGY

Lesson 1: An Overview of Biotechnology

Competency/Objective: Summarize the importance of biotechnology to agriculture.

Study Questions

1. **What is biotechnology?**
2. **What has been the role of biotechnology in agriculture?**
3. **What is the current role of biotechnology in agriculture?**
4. **How does agricultural biotechnology influence consumer perspectives?**
5. **How does agricultural biotechnology influence producer perspectives?**
6. **What other areas of life have been affected by biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit I.
2. Suggested reference: Access Excellence's "Basic Biotechnology for Beginning Teachers" at http://www.gene.com/ae/AE/AEPC/WWC/1993/basic.html.
3. Activity Sheet

   AS 1.1: What is . . . ? Facts about Biotechnology

UNIT I - INTRODUCTION TO BIOTECHNOLOGY

Lesson 1: An Overview of Biotechnology

TEACHING PROCEDURES

A. Introduction

Biotechnology has been around for thousands of years. Almost every seed that a producer plants today is a result of crossbreeding and hybridization, which are aspects of biotechnology. Selective breeding and crossbreeding are forms of biotechnology that are standard practices in the livestock industry. Modern biotechnology takes traditional methods of crop and livestock production to a new level. Instead of breeding whole plants or animals to produce a desired trait, modern biotechnology makes it possible to transfer specific traits from one organism to another.

B. Motivation

1. Show the video "Fields of Promise" (Monsanto, 27 min.) available from MVRC.

2. Discuss the size of the biotechnology industry in the United States. Point out that in 1993, 1,300 biotechnology companies in the United States employed 80,000 people and generated $8.1 billion in annual sales. The industry has grown since 1993. Speculate on the future of the industry.

3. Bring two tomatoes to class, one from a home garden and one from a grocery store. Ask the class to compare the way they look. Drop each tomato from a height of five feet into a trash can. Did one squash or splatter more than the other? Discuss why.

C. Assignment

D. Supervised Study

E. Discussion

1. Have students define "biotechnology" in their own words. Write these definitions on the board and then compile them into one working definition. Point out the broad scope of biotechnology and that many different definitions exist.

What is biotechnology?

a) Biotechnology can be defined as the application of scientific principles to living things. It involves harnessing the natural biological processes of cells from microorganisms, animals, and plants to develop useful products.
b) A narrower definition of modern biotechnology includes only those processes that involve the recombination of genes from living things in a laboratory setting.

2. Have students identify examples of agricultural biotechnology. Point out that yeast was first used to brew beer and make wine as long ago as 6,000 B.C. Cheese, yogurt, bread, and cider are all common products of biotechnology. More information about the history of biotechnology is available on the Internet at the Access Excellence website "About Biotech: The Biotech Chronicles" at http://www.gene.com/ae/AB/BC/index.html.

What has been the role of biotechnology in agriculture?

a) Crop production
   1) Greeks developed fruit tree grafting techniques (300 B.C.).

2) Gregor Mendel experimented with garden peas, discovering the foundations of genetics (1865).
3) The first hybrid corn plant was developed in the United States (1879).
4) Improved wheat and rice varieties were developed internationally (1946-1965).

b) Animal production
1) Selective breeding of livestock was practiced by people in the Middle East (18,000 B.C.).
2) Animal crossbreeding and purebreeding were practiced in Europe (1500 A.D.)
3) A procedure for artificial insemination was first developed in Italy (late 1700s).

c) Agricultural processing
1) The use of bacteria to make cheese, bread, and alcohol began in Egypt (4,000-2,000 B.C.).
2) The modern distillery was invented in United States (1830).
3) Louis Pasteur discovered that fermentation was carried out by bacteria and confirmed the existence of microorganisms, leading to applications such as the large scale brewing of beer and wine (1860s).

3. Use newspaper articles or Internet sites to show examples of current developments in agricultural biotechnology.

What are the emerging areas of agricultural biotechnology?

a) The modern era of biotechnology began with the first successful recombination of DNA (1973).
b) The technique of plant tissue culture was developed (late 1970s).
c) New technologies have been developed in animal biotechnology.
1) Embryo transfer techniques were developed (early 1980s).
2) A Chinese scientist cloned a fish (1981).
3) The first adult mammal was cloned in Scotland (1997).
4) A calf was cloned from cells taken from a 30-day-old fetus (1997).
d) The ability to alter DNA through genetic engineering has made many new products possible.
1) The first genetically modified food product, an enzyme used in making cheese, was approved for use in the United States (1990).
2) The first genetically modified crop plant, a tomato plant, was approved in the United States (1994).
3) Insect-resistant and herbicide-tolerant crops were approved in the United States (1995-1996).
4) Animal vaccines were produced by genetically modified bacteria (mid-1990s).
e) Future biotechnology products may include environmentally tolerant crops or genetically modified plants used as biofuels.

4. Ask students if they have ever helped buy food at a grocery store. Ask them how they would decide whether to buy vegetables that have been genetically modified.

How does agricultural biotechnology influence consumer perspectives?

a) Positive
1) Lower food costs
2) Increased nutrient content of food
3) Availability of fresh fruits and vegetables year-round
4) Increased and cheaper food supply in developing countries

b) Negative
1) Fear of unsafe foods
2) Fear of environmental damage from genetically altered organisms

5. Ask students if they know of any local producers who plant genetically modified seed or use other inputs developed through agricultural biotechnology.

How does agricultural biotechnology influence producer perspectives?

a) Positive
   1) Increased profits from higher yields or lower input costs
   2) Reduction in the amount of chemicals used
   3) Profitable customized crops
b) Negative
   1) Fear that small farms may not have the opportunity to use biotechnology and be forced out of business by more competitive, large corporate farms
   2) Fear of the creation of "super weeds"

6. Ask if anyone knows someone who is diabetic and must take insulin injections. Explain that improved insulin from bacteria modified to produce human insulin is one example of a nonagricultural advancement in biotechnology.

What other areas of life have been affected by biotechnology?

a) Human health industry
   1) Pharmaceuticals
      (a) Insulin produced by bacteria
      (b) Genetically engineered vaccines
      (c) Antibiotics and growth hormones
   2) Tests for detecting genetic disorders
      (a) Huntington's disease
      (b) Down's syndrome
      (c) Tay-Sachs disease
      (d) Cystic fibrosis
b) Biomining - modified bacteria that break down metal ore
c) Forensics - DNA fingerprinting
d) Waste management
   1) Bacteria that break down sewage
   2) Bacteria that clean up crude oil spills
   3) Bacteria that improve soil contaminated with organic compounds
   4) Bacteria that feed on solid waste and produce methane gas for fuel

F. Other Activities

1. Show a video such as "Green Cows, Quags, and Mummies," available from MVRC.

2. Have students conduct an Internet search using the term "agricultural biotechnology" and report on their findings.

G. Conclusion

The biotechnology industry is large and is expanding at a rapid rate. New products and processes will be developed as long as a market exists for them, and agriculture will change as they are developed. How will producers and consumers react to new products? Will the products of biotechnology pose risks to humans, animals, or the environment? While the answers to these questions are not yet clear, biotechnology will have a huge impact on agriculture and many other industries.

H. Answers to Activity Sheet

AS 1.1

1. Biomining
2. Dolly
3. 1879
4. Genetic engineering
5. DNA fingerprinting
6. Egypt
7. Plant tissue culture
8. Corn
9. Biotechnology
10. Customized crop
11. 18,000 B.C.
12. 1973
13. Human insulin
14. FlavrSavr™ tomato

I. Answers to Evaluation

1. b
2. c
3. d

4. Fear that small farms will lose money on biotechnology and be forced out of business by large corporate farms; fear of the development of "super weeds"

5. Fear of unsafe foods; fear of environmental damage from genetically altered organisms

6. Biotechnology can be defined as the application of scientific principles to living things. It involves harnessing the natural biological processes of cells from microorganisms, animals, and plants to develop useful products.

UNIT I - INTRODUCTION TO BIOTECHNOLOGY Name _____

Lesson 1: An Overview of Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. The first successful recombination of DNA took place in:

   a. 1963
   b. 1973
   c. 1983
   d. 1993

2. Which of the following is an example of a human pharmaceutical that was developed through biotechnology?

   a. Drugs for Down's syndrome
   b. Vaccine for Tay-Sachs disease
   c. Insulin for diabetics
   d. Antibiotics for Huntington's disease

3. In what place and time period did the use of bacteria to make cheese, bread, and alcohol begin?

   a. Greece, 300 B.C.
   b. Greece, 4,000 to 2,000 B.C.
   c. Egypt, 300 B.C.
   d. Egypt, 4,000 to 2,000 B.C.

Complete the following short answer questions.

4. What are two concerns of producers about biotechnology?

5. What are two consumer concerns about biotechnology?

6. What is biotechnology?

Lesson 1: An Overview of Biotechnology Name _____

What is . . . ? Facts about Biotechnology

Objective: Identify facts about biotechnology.

Using your *Biotechnology: Applications in Agriculture* student reference, read the description in the column titled "Answers" and write in the corresponding term that completes the question.

Answers	What is . . . ?
1. Using modified bacteria to break down metal ore	1. _____
2. Name of the ewe that was the first animal cloned from an adult mammal	2. _____
3. The year that the first hybrid corn was developed in the United States	3. _____
4. A technology used to alter the genetic material of living cells to give them new characteristics	4. _____
5. Process used in the application of biotechnology to forensics	5. _____
6. The country where bacteria were first used to make cheese, bread, and alcohol	6. _____
7. Growing a full-sized plant from a few plant cells	7. _____
8. The first hybrid crop plant	8. _____
9. The application of scientific principles to living things	9. _____
10. Corn developed especially for the production of ethanol	10. _____
11. The earliest date that selective breeding was practiced	11. _____
12. The year that modern biotechnology began	12. _____
13. The first genetically engineered product approved for sale	13. _____
14. The first genetically modified crop plant approved in the U.S.	14. _____

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 1: Challenges to Biotechnology

Competency/Objective: Explain the major issues associated with agricultural biotechnology.

Study Questions

1. **What are the major issues associated with the use of biotechnology in agriculture?**
2. **What are the food safety issues associated with genetically modified foods?**
3. **What are the labeling issues associated with genetically modified foods?**
4. **What are the issues related to releasing genetically altered plants and animals into the environment?**
5. **What are the animal welfare issues raised by agricultural biotechnology?**
6. **What are other moral issues concerning agricultural biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit II.
2. Transparency Masters
   a) TM 1.1: Results of the Community Survey
   b) TM 1.2: Summary of Data
3. Activity Sheets
   a) AS 1.1: Community Survey (Instructor)
   b) AS 1.1: Community Survey (Student)

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 1: Challenges to Biotechnology

TEACHING PROCEDURES

A. Introduction

New technology has always sparked controversy, and biotechnology is no exception. Many ethical issues are emerging as genetic manipulation is used more frequently. This lesson will outline some current issues in biotechnology.

B. Motivation

Bring in two glasses of milk, types of cheese, carrots, tomatoes, or other vegetables. Ask students to taste them to see if they can tell a difference. Tell the students that one sample could be a product of biotechnology. Ask students if they think that both of the samples are safe. How would they know if a food was genetically modified? Would they even care?

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students for examples of issues in biotechnology that they have seen in the news.

   What are the major issues associated with the use of biotechnology in agriculture?

   a) Safety of genetically modified food
   b) Labeling of genetically modified foods
   c) Safety of releasing genetically modified organisms into the environment
   d) Animal welfare issues
   e) Morality of genetic engineering

2. Ask students how they felt when told that the one of the samples of milk, cheese, or vegetables might be a product of biotechnology. Discuss the difference between perception of safety and actual safety.

   What are the food safety issues associated with genetically modified foods?

   a) The Food and Drug Administration (FDA) states that genetically engineered foods are as safe as or safer than other foods, since they must meet the same standards; many scientific studies show no differences in the chemical composition of modified and unmodified foods.
   b) Some consumers, including some restaurants and chefs, have refused to use genetically altered food, because they claim the government has not done enough to ensure their safety.
   c) Some scientists caution that since no long-term studies have been done on the effects of modified foods on human health, their long-term safety is unknown.
   d) Other consumers fear that modified foods may have genes that cause allergic reactions or reduce the effectiveness of antibiotics (through the use of antibiotic-resistant genes during the process of genetic engineering).

3. Discuss the pros and cons of labeling food as genetically modified.

What are the labeling issues associated with genetically modified foods?

a) Some people argue that the public has a right to know if food has been genetically engineered to be able to make an informed decision about whether to buy it.
   1) Some people view genetic modifications as unacceptable for religious reasons.
   2) Vegetarians may want to avoid modified foods because they may contain genes taken from animals.

b) The FDA's policy is that since genetically modified foods are no different from other foods, no need exists for labeling them as modified, with two exceptions.
   1) The FDA requires a label for foods with a gene that could cause an allergic reaction.
   2) The FDA requires a label if genetic engineering makes a significant change in a food's composition.

4. Ask students if they have seen vegetables in a garden cross-pollinate and produce different fruit. Discuss the possible problems associated with releasing genetically altered organisms.

What are the issues related to releasing genetically altered plants and animals into the environment?

a) Releasing genetically modified organisms into the environment may introduce altered genes into native populations, giving them undesired traits.
b) Releasing modified organisms may reduce biodiversity, if unmodified organisms are unable to compete.

5. Ask students to discuss what treating animals humanely means.

What are the animal welfare issues raised by agricultural biotechnology?

a) Some people question whether it is morally right to genetically engineer an animal to alter its natural ability to produce.
b) Some people argue that altering animals to produce pharmaceuticals and other health products for humans is inhumane.

6. Ask students about other ethical reasons that people oppose genetic engineering. Have students complete AS 1.1. Use TM 1.1 to tabulate the results of the surveys. TM 1.2 can be used to further illustrate the results.

What are other moral issues concerning agricultural biotechnology?

a) Some people view genetic manipulation as "playing God," which oversteps the boundaries of what is appropriate for humans.
b) Genetic manipulation may permanently alter the balance of nature.

F. Other Activities

1. Have a spokesperson who favors genetic engineering and one who is against it speak to the class. The Union of Concerned Scientists is a possible source of speakers opposed to biotechnology. University research programs and biotechnology companies such as Monsanto are good sources of biotechnology speakers in favor of genetic engineering. An Internet search may help locate speakers.

2. Have students debate the issue of labeling genetically altered foods. Divide the class into two groups, with one group favoring labeling and the other group opposing it. Have each group collect information that supports its position and then hold a formal debate in class.

3. Have students conduct an Internet search to identify additional issues connected to biotechnology.

G. Conclusion

Agricultural biotechnology promises to raise food production to a new level, but concerns held by the public may slow its acceptance. Food safety and labeling, environmental concerns, and moral issues all need to be addressed so that the public has confidence in the use of biotechnology in agriculture.

H. Answers to Activity Sheet

AS 1.1

Answers will vary.

I. Answers to Evaluation

1. d
2. c

3. Students may give either of the following answers: some people question whether it is morally appropriate to genetically engineer an animal to exceed its natural ability to produce, or some people argue that altering animals for pharmaceuticals and health products for humans is inhumane.

4. Some scientists argue that releasing genetically modified organisms into the environment is dangerous because they may introduce altered genes into native populations, giving them undesired traits. Others argue that releasing modified organisms will decrease biodiversity, because unmodified organisms will be unable to compete.

5. Answers may be either of the following: genetic engineering is "playing God," or genetic engineering could alter the balance of nature.

UNIT II - ISSUES IN BIOTECHNOLOGY Name _____

Lesson 1: Challenges to Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is not a major issue associated with the use of biotechnology?

   a. The safety of genetically engineered foods for human consumption
   b. The welfare of animals on which biotechnology is used
   c. The labeling of modified foods as products of biotechnology
   d. The exploitation of the microorganisms used in genetic engineering

2. When does the FDA require products of biotechnology to be labeled?

   a. Whenever foreign genetic material is introduced into a plant
   b. Whenever a gene from an animal is introduced into a plant
   c. Whenever a gene that could cause an allergic reaction is used
   d. Whenever a gene that is antibiotic-resistant is used

Complete the following short answer questions.

3. What is one issue raised by people who are concerned about the use of biotechnology on animals?

4. What are two reasons that some scientists question the safety of releasing genetically modified plants into the environment?

5. What is one reason that genetic manipulation may be considered morally wrong?

Results of the Community Survey

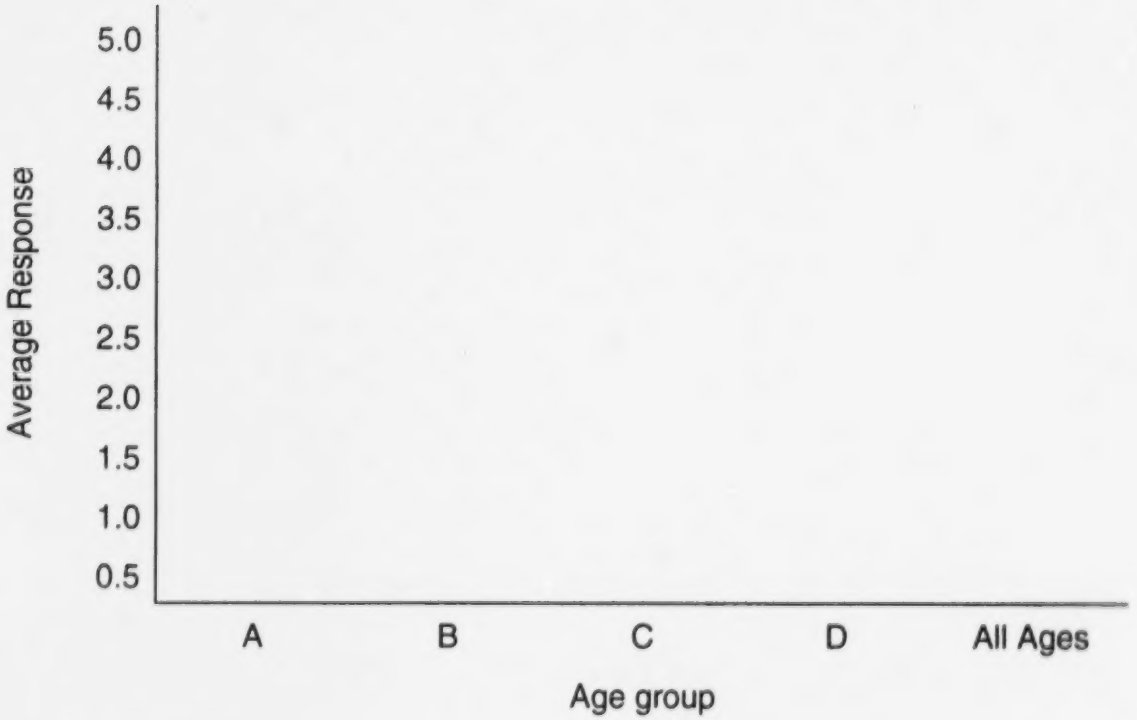
Question Number	Category A <20 yrs old Average Score	Category B 20 - 40 yrs old Average Score	Category C 40 - 60 yrs old Average Score	Category D over 60 yrs old Average Score	Overall Score
1					
2					
3					
4					
5					
6					
7					

6-II

TM 1.1

Summary of Data

Question #_____



II-11

TM 1.2

39

Lesson 1: Challenges to Biotechnology

Community Survey

Objective: Investigate the reactions of the public to agricultural biotechnology.

1. Give each student four copies of AS 1.1, since they must interview four people.

2. When they have finished, collect the completed surveys from the students and have them assist in sorting, tabulating, and recording the survey results. TM 1.1 is provided to help tabulate the results of the survey. The results of the survey could also be given to a statistics class for further analysis or assigned to an advanced student for further analysis of the differences in responses by gender.

3. Sort the surveys by age group: <20 (Group A), 20-40 (Group B), 40-60 (Group C), and >60 (Group D).

4. Beginning with Group A, write the scores of the first question on the board. Find the average score for the question and record it on TM 1.1. Repeat this process for each age category.

5. Find the average score for each question using all of the surveys, and record the score in the "Overall Score" column of the transparency.

6. A bar graph has been included in TM 1.2 that can be used to compare the response for each question.

7. Interpret the data. An average median score of 2.5 for a statement shows that the community is neutral about it. A score greater than 2.5 shows an attitude that supports the statement. A score less than 2.5 shows an attitude that does not support the statement. Discuss the attitudes revealed by this survey. Is age a factor in the attitudes displayed by the community? What is the overall perception of biotechnology in the community? Discuss the limitations and accuracy of this survey and its results.

   Note: Some statements are positive, while others are stated in a negative form. Response scores must be interpreted in the context of the original form of the statement.

Lesson 1: Challenges to Biotechnology Name _____

Community Survey

Objective: Investigate the reactions of the public to agricultural biotechnology.

To understand current societal attitudes toward agricultural biotechnology in your community, use the statements below to survey four people. Survey one person from each age group. Record each person's approximate age and gender and their level of agreement or disagreement with each statement.

Age Group (circle one): Under 20 20-40 40-60 Over 60

Gender: Male Female

1. Foods products from genetically modified plants are safe to eat.

   1 Strongly disagree 2 Disagree 3 Agree 4 Strongly agree

2. Genetically modified crops pose no real threat to nature or the environment.

   1 Strongly disagree 2 Disagree 3 Agree 4 Strongly agree

3. Genetically modified foods sold in a grocery store should carry a label that states that they are genetically modified.

   1 Strongly disagree 2 Disagree 3 Agree 4 Strongly agree

4. Genetically modifying animals is inhumane.

   1 Strongly disagree 2 Disagree 3 Agree 4 Strongly agree

5. Genetically modifying plants is morally wrong.

   1 Strongly disagree 2 Disagree 3 Agree 4 Strongly agree

6. Genetically modifying animals is morally wrong.

   1 Strongly disagree 2 Disagree 3 Agree 4 Strongly agree

7. Genetic engineering will significantly increase food production over the next ten years.

   1 Strongly disagree 2 Disagree 3 Agree 4 Strongly agree

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 2: Agencies Involved in Biotechnology

Competency/Objective: Identify government agencies involved in biotechnology.

Study Questions

1. **What is the role of the Environmental Protection Agency (EPA) in biotechnology?**
2. **What is the role of the United States Department of Agriculture (USDA) in biotechnology?**
3. **What is the role of the Food and Drug Administration (FDA) in biotechnology?**
4. **What is the role of the Occupational Health and Safety Administration (OSHA) in biotechnology?**
5. **What is the role of the National Institutes of Health (NIH) in biotechnology?**
6. **What is the role of the Nuclear Regulatory Commission (NRC) in biotechnology?**
7. **How is the international trade of biotechnology products regulated?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit II.
2. Activity Sheet
   a) AS 2.1: Solving the Regulatory Puzzle

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 2: Agencies Involved in Biotechnology

TEACHING PROCEDURES

A. Review

The first lesson of this unit discussed several issues concerning biotechnology. These issues may be addressed by federal agencies. Federal agencies have been given the responsibility of overseeing areas such as food and environmental safety. This lesson reviews the roles that each of these agencies plays in monitoring biotechnology.

B. Motivation

1. Ask students, "Have any of you ever been concerned about buying or eating food that was unsafe?" Remind the students of instances when meat was contaminated with the *E. coli* bacteria. How does one know that America's food supply is safe? The federal government has answered this question by giving the responsibility of safeguarding America's food supply to a federal agency known as the Food and Drug Administration (FDA).

2. Write the following acronyms on the chalkboard and have students identify the agency: FDA, EPA, USDA, OSHA, NIH, and NRC. Ask students to describe the role of each agency in biotechnology.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students for examples of areas that the EPA regulates. Explain the EPA's role in overseeing biotechnology.

What is the role of the Environmental Protection Agency (EPA) in biotechnology?

a) The EPA regulates any pesticidal quality that might be present in plants that have been genetically engineered.
   1) The EPA must issue an experimental use permit before approving a field test for a modified plant.
   2) The applicant for the permit must submit a detailed plan of the proposed field test.
b) The EPA regulates the use of pesticides on genetically modified plants.
c) All genetically modified microorganisms are regulated by the EPA.

2. Discuss examples of the areas of biotechnology that the USDA oversees.

What is the role of the United States Department of Agriculture (USDA) in biotechnology?

a) Funds research in biotechnology
b) Regulates agricultural research and products through its Animal and Plant Health Inspection Service (APHIS)
   1) APHIS requires permits for the field testing, shipping, and delivery of any seed or plant modified through biotechnology. In 1993 an exception to the prior approval requirement was made for six crops (corn, soybeans, cotton, potatoes, tobacco, and tomatoes) that have a history of safe genetic modification. Only notification 30 days prior to field testing modified crops is required.

2) APHIS reviews how research was conducted and its results and outlines possible concerns posed by the release of the new crop or product.

3. Discuss with students the important role that the FDA plays in regulating biotechnology.

What is the role of the Food and Drug Administration (FDA) in biotechnology?

a) The FDA, which is responsible for ensuring the safety of the nation's food supply, issued a statement in 1992 that is the basis of its policy concerning plant biotechnology.
   1) Genetically modified food products or food additives will be regulated in the same way as food products or additives produced by other means; only the characteristics of the food are important.
   2) The FDA allows foods to be introduced to the commercial market with notification of its planned introduction.
   3) The FDA has the power to remove a food from the market if it suspects the food is unsafe.
   4) Approval prior to marketing is required for some genetically modified foods; they may have to be labeled as well.
      (a) Foods containing a substance known to cause allergic reactions
      (b) Foods in which the nutritional value has changed
      (c) Foods that contain genetic material from a source not currently in the food supply

b) The FDA also regulates all drugs and drug delivery systems, including genetically engineered animal vaccines.

4. Ask students to describe what they know about OSHA. Explain that most companies are required to follow OSHA safety regulations.

What is the role of the Occupational Safety and Health Administration (OSHA) in biotechnology?

OSHA's mission is "to save lives, prevent injuries, and protect the health of American workers." OSHA's involvement in agricultural biotechnology is primarily to ensure that workers in biotechnology work in a safe environment.

5. Ask students to describe the NIH and to explain its role in biotechnology.

What is the role of the National Institutes of Health (NIH) in biotechnology?

a) NIH is a federally funded agency whose mission is "to uncover new knowledge that will lead to better health for everyone;" it is involved in biotechnology in many ways.
   1) Conducts research in biotechnology in its own laboratories
   2) Supports the research of nonfederal scientists in various public and private institutions within and outside of the United States
   3) Helps in training of research scientists by funding graduate student research efforts
   4) Fosters biomedical communication

b) NIH regulates the research that it funds through a set of guidelines, but has no control over other research.

c) Many researchers in both public and private institutions voluntarily follow NIH guidelines.

6. Ask students if they know when the NRC was established (1974). Note that the primary role of the NRC is regulating nuclear reactors. Discuss the NRC's role in overseeing biotechnology.

What is the role of the Nuclear Regulatory Commission (NRC) in biotechnology?

a) Regulates the use of radioactive materials by academic and industrial biotechnology research laboratories
b) Requires a special permit for the transport, handling, storage, and disposal of radioactive materials

7. Ask students if they know of any other agencies that might be involved in overseeing biotechnology. Discuss the international trade of products of biotechnology and how it is regulated. Have students complete AS 2.1.

How is the international trade of biotechnology products regulated?

International committees are meeting to try to establish voluntary guidelines for the movement of genetically modified organisms between nations.

F. Other Activities

1. Have a guest speaker (e.g., county health or local environmental employee) discuss biotechnology.

2. Have students do research and write a report on different regulatory agencies.

G. Conclusion

Many federal agencies are involved in overseeing biotechnology. Some companies have complained that they are required to complete unnecessary steps to comply with the inflexible rules of these agencies. Some consumer groups complain that the agencies responsible for monitoring biotechnology are not trained in biotechnology and know little about it. Still other people feel that these agencies are doing an adequate job in regulating biotechnology. However, nearly everyone agrees that some regulation is needed.

H. Answers to the Activity Sheet

1. Approval/permits: EPA - to obtain an experimental use permit due to pesticidal properties
   FDA - due to the change in the composition of the potato
   Notifications: USDA - notification required prior to field testing

2. Approval/permits: EPA - to obtain an experimental use permit due to pesticidal properties
   USDA - to obtain a field test permit
   Notifications: FDA - notification required for the planned introduction of a new food product

I. Answers to Evaluation

1. b
2. c
3. b
4. c
5. a
6. d
7. d

8. The NRC regulates the use of radioactive materials by academic and industrial biotechnology research laboratories. It requires a special permit for the transport, handling, storage, and disposal of radioactive materials.

9. The FDA evaluates genetically modified food products or food additives in the same way as food products or additives produced by other means. Only the characteristics of a food are important.

10. International committees are meeting to try to establish voluntary guidelines for the movement of genetically modified organisms between nations.

UNIT II - ISSUES IN BIOTECHNOLOGY Name _____

Lesson 2: Agencies Involved in Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. The Animal and Plant Health Inspection Service (APHIS) is a part of the:

   a. Environmental Protection Agency (EPA)
   b. United States Department of Agriculture (USDA)
   c. Food and Drug Administration (FDA)
   d. National Institutes of Health (NIH)

2. The federal agency that regulates the labeling of a food is the:

   a. Environmental Protection Agency (EPA)
   b. United States Department of Agriculture (USDA)
   c. Food and Drug Administration (FDA)
   d. National Institutes of Health (NIH)

3. What agency regulates the environment in which employees work in agricultural biotechnology?

   a. Environmental Protection Agency (EPA)
   b. Occupational Safety and Health Administration (OSHA)
   c. Food and Drug Administration (FDA)
   d. National Institutes of Health (NIH)

4. The National Institutes of Health (NIH) performs which of the following roles in overseeing biotechnology?

   a. NIH plays a major role in regulating the health and safety aspects in all biotechnology laboratories.
   b. NIH uses a set of guidelines to regulate drug research in all public research institutions.
   c. NIH can only regulate research that it funds, but its guidelines influence the actions of many other researchers.
   d. NIH is not involved in regulating biotechnology research.

5. From which agency must a researcher obtain an experimental use permit?

   a. Environmental Protection Agency (EPA)
   b. Food and Drug Administration (FDA)
   c. Occupational Safety and Health Association (OSHA)
   d. National Institutes of Health (NIH)

6. A new corn plant genetically modified to resist the European corn borer would need approval from which of the following agencies?

   a. Nuclear Regulatory Commission (NRC)
   b. National Institutes of Health (NIH)
   c. Occupational Safety and Health Administration (OSHA)
   d. Environmental Protection Agency (EPA)

7. A genetically modified bacteria that helps wheat use nitrogen from the air would need approval from which two agencies?

   a. FDA and EPA
   b. USDA and NRC
   c. NIH and OSHA
   d. EPA and USDA

Complete the following short answer questions.

8. What is the role of the Nuclear Regulatory Commission (NRC) in regulating biotechnology?

9. How does the FDA regulate genetically modified foods or food additives?

10. How are nations attempting to regulate the international trade of organisms created using biotechnology?

Lesson 2: Agencies Involved in Biotechnology Name _____

Solving the Regulatory Puzzle

Objective: Identify the agencies involved in overseeing biotechnology.

Read the following paragraphs that describe genetically modified agricultural products that are or could be developed. List the agencies that must be notified about the product and those from which approval or a permit must be secured. Explain why each agency must be contacted.

1. Monsanto has developed a potato called the NewLeaf® potato that can protect itself from the Colorado potato beetle. This insect can destroy a field of potatoes in two or three days by stripping the plants of their leaves. If this potato was further modified to produce potatoes with a higher solids content that absorbs less oil when cooked, what are the regulatory requirements that Monsanto would have to meet?

   a) Approval/permits needed:

   b) Notifications needed:

2. *Bacillus thuringiensis (Bt)* is a naturally occurring bacterium found in the soil that is noted for its ability to control pests. Gardeners have been using *Bt* as a biological insecticide spray for nearly 100 years. Many crops are being developed that will contain *Bt* genes. If a carrot was developed containing this gene, what regulatory requirements would its developer need to meet?

   a) Approval/permits needed:

   b) Notifications needed:

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 3: Biotechnology Patents

Competency/Objective: Identify procedures involved in obtaining a patent for a biotechnology product.

Study Questions

1. **What is a patent?**
2. **What are the requirements for obtaining a utility patent for a product of biotechnology?**
3. **What are the issues surrounding the patenting of biotechnology products?**
4. **What is DNA fingerprinting?**
5. **What are the problems associated with the handling of genetic material?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit II.
2. Transparency Master
   a) TM 3.1: Section of a DNA Fingerprint
3. Activity Sheet
   a) AS 3.1: Patent Debate

UNIT II - ISSUES IN BIOTECHNOLOGY

Lesson 3: Biotechnology Patents

TEACHING PROCEDURES

A. Review

Lesson 2 discussed various regulatory agencies that affect the development of products using biotechnology. Before marketing or even field testing such a product, the developer usually secures a patent to protect the research investment. Patents for biotechnology products have played a major role in shaping the biotechnology industry. Companies have purchased other companies just to obtain certain patents. However, strong opposition to patenting genetically modified life forms has developed. This lesson will discuss patents and the issues surrounding patenting products of biotechnology.

B. Motivation

1. In 1996, biotechnology generated nearly $13 billion in annual revenues in the United States. The value of biotechnology patents ranges from millions of dollars to less than the patent application fee itself. Many people refer to this search for profitable patents as a high-tech gold rush. Few prospectors will strike it rich, but many will dig for gold.

2. Using an ink pad and small Post-It™ notes, have each student make a copy of his or her fingerprint. Display them to the class to show the differences. Discuss the process of genetic fingerprinting.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students what a patent is. Discuss examples of products that have been patented (including plants and animals).

What is a patent?

a) A patent grants property rights that exclude others from making, using, or selling the patented invention throughout the United States for a stated period of time, normally 17 years.

b) The U.S. Patent and Trademark Office grants three types of patents.

1) Utility patent - granted for "new and useful" inventions that meet certain statutory requirements; the most common type of patent

2) Plant patent - issued to anyone who invents or discovers and asexually reproduces any new variety of plant, including cultivated spores, mutants, hybrids, and newly found seedlings

3) Design patent - granted for any new, original, and ornamental design for a manufactured article

2. Ask students what is required to obtain a patent. Discuss the requirements for obtaining a utility patent.

What are the requirements for obtaining a utility patent for a product of biotechnology?

a) Statutory requirements
   1) The invention must be a new and useful process, machine, manufactured item, or composition of matter; most biotechnology products fall into the "composition of matter" category since they are essentially rearrangements of DNA.
   2) The invention must be novel and nonobvious. An invention is obvious if it can be readily deduced from information available to the public by a person knowledgeable in the relevant technological field.
   3) The invention must be fully described and clearly claimed in a patent application.

b) Additional qualifications
   1) The invention must be patentable. The laws of nature, physical phenomena, and abstract ideas are not patentable.
   2) A patent cannot remove anything from the public domain. This means that something already commonly used cannot be patented.
   3) The granting of the patent must add adequate information about the invention to the public domain.

3. Discuss with students whether they think it is acceptable to patent life-forms. Have students complete the debate outlined in AS 3.1.

What are the issues surrounding the patenting of biotechnology products?

a) The question of ownership of genetically modified organisms
b) The patenting of the genetic material of plants and animals native to countries other than the United States

4. Ask students what makes fingerprints different. Just as the different line patterns make each fingerprint unique, the different locations of bands on an electrophoresis gel make each DNA fingerprint unique.

What is DNA fingerprinting?

a) DNA fingerprinting is the process of using laboratory analysis of DNA to generate a pattern that is unique to an individual organism.
b) DNA fingerprinting involves several steps.
   1) Isolating the DNA
   2) Cutting, sizing, and sorting the DNA
   3) "Tagging" the DNA with a probe dye

5. Discuss some of the problems associated with handling genetic material.

What are the problems associated with the handling of genetic material?

a) Preventing the theft of genetic material
b) Flawed results from testing
c) Preserving the privacy of genetic information

F. Other Activities

Have students further research the controversy surrounding patents on biotechnology by focusing on the issue of whether the government should have the right to grant itself patents. Have the students research cases in which the U.S. government issued a patent to itself for a product of biotechnology. Encourage students to use the Internet in their research.

G. Conclusion

Patents play an important role in the biotechnology industry. Biotechnology companies view patents as vital because they protect their research investments. However, patents on genetic material and products of biotechnology have sparked new debate as to exactly what should be eligible for a patent. Ultimately, U.S. courts will have to decide the answer to this difficult question as lawsuits are filed to challenge certain patent rights.

H. Answers to Activity Sheet

AS 3.1

Answers will vary.

I. Answers to Evaluation

1. b
2. a
3. c

4. DNA fingerprinting is the process of using the laboratory analysis of DNA to generate a pattern that is unique to an individual organism.

5. The question of ownership of genetically modified organisms and the patenting of the genetic material of plants and animals native to countries other than the United States

6. Preventing the theft of genetic material, flawed results from testing, and preserving the privacy of genetic information

Name _____

Lesson 3: Biotechnology Patents

Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. A patent is the:

   a. Permanent right to the profits received from the marketing of the patented invention.
   b. Right to exclude others from making, using, or selling the patented invention.
   c. Right to keep confidential the details of an invention.
   d. Temporary right to use an invention in the United States.

2. The most common type of patent obtained for an invention using biotechnology is the:

   a. Utility patent.
   b. Design patent.
   c. Plant patent.
   d. Genetic patent.

3. Which of the following is <u>not</u> a statutory requirement for a utility patent?

   a. The invention must be a new and useful process, machine, manufactured item, or composition of matter.
   b. The invention must be novel and nonobvious.
   c. The invention must be an abstract idea.
   d. The invention must be fully described and clearly identified in the patent application.

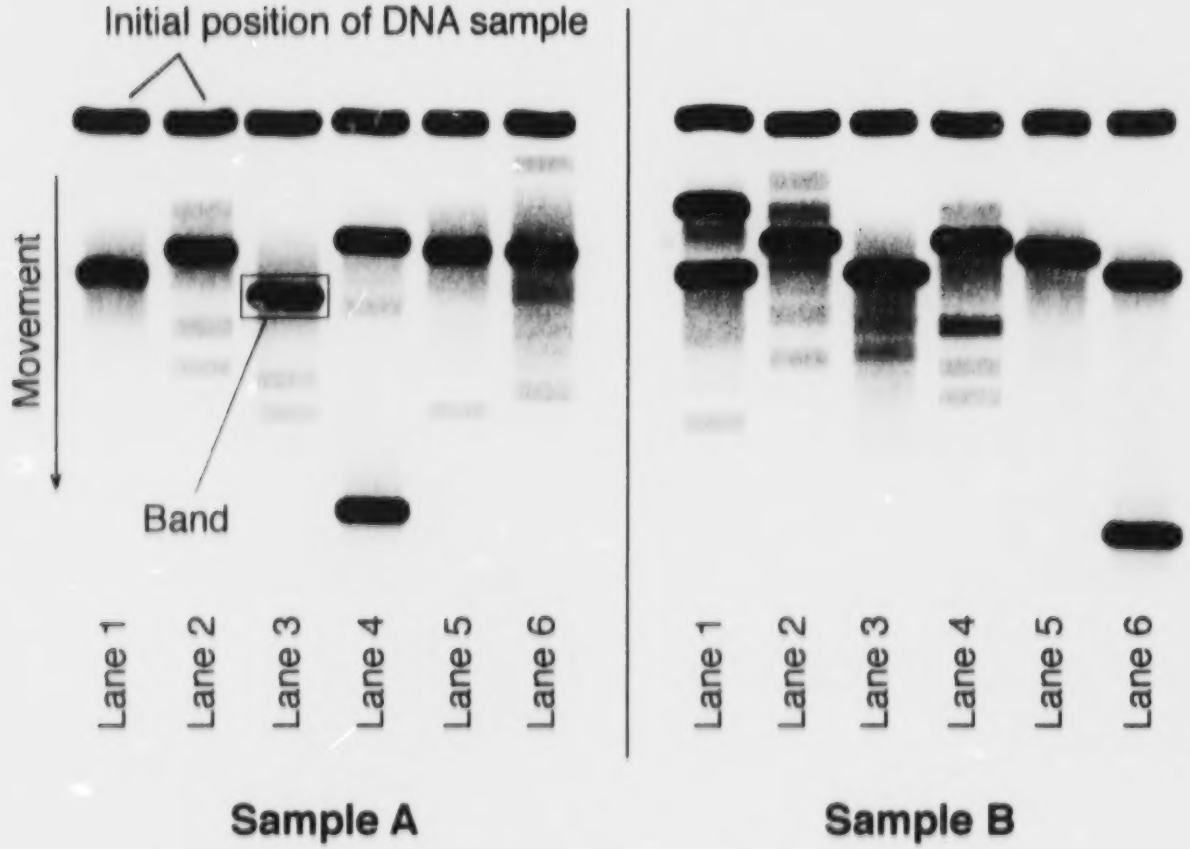
Complete the following short answer questions.

4. What is DNA fingerprinting?

5. What are the issues surrounding the patenting of biotechnology products?

6. What problems exist with the handling of genetic material?

Section of a DNA Fingerprint



Do the bands in Sample A match the bands in Sample B?

Patent Debate

Objective: Examine issues surrounding the patenting of products of biotechnology.

Your instructor will divide the class into two groups. The first group represents the scientists and the corporations who want to strengthen their right to patent biotechnology products. The second group represents the groups opposed to patenting life-forms. Each group should search the Internet and other sources for information that will support their argument. The questions below should be used to help guide the research. A group must have four major arguments to support its case and be ready to answer the other group's objections. Select one person in each group to record the arguments and answers to possible objections.

- Are patents necessary to protect the monetary investment made by researchers in developing useful products?
- Should plant, animal, or human DNA be patented, since it is not an invention?
- Who owns or controls the genes of plants and animals?
- What international trade problems have arisen or could arise due to patents on genetically modified plants and animals?

Your teacher will moderate the debate. Each side will take turns making a point and then giving the other group the opportunity to raise an objection to the point. This process will continue until both groups have raised their four points. Each group will then be given a short time for closing arguments.

UNIT III: BASIC LABORATORY SKILLS

Lesson 1: The Scientific Method

Competency/Objective: Describe the steps in the scientific method.

Study Questions

1. **What are the steps of the scientific method?**
2. **Why is it important to follow the scientific method?**
3. **What information should a laboratory notebook include?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998. Unit III.
2. Activity Sheet
   a) AS 1.1: Using the Scientific Method

UNIT III: BASIC LABORATORY SKILLS

Lesson 1: The Scientific Method

TEACHING PROCEDURES

A. Introduction

This unit will introduce some basic laboratory skills that are important in almost every type of biotechnology research. This lesson focuses on the scientific method and its application in biotechnology. The scientific method is an important and widely used research strategy. Scientific research is essentially a rational and logical search for answers to scientific questions. This search must be done in a calculated way to increase the chances of finding the desired answer.

B. Motivation

Trip the breaker for the classroom. Have students use the scientific method to analyze the problem. Guide them through the process using the steps below.

Step 1: Identify the problem. (Why are the lights in the classroom off?)

Step 2: Research the available information. (Is the switch on, are there light bulbs in the sockets, have the lights been on before, etc.?)

Step 3: Formulate a hypothesis. (The lights went off because the breaker was tripped.)

Step 4: Design the investigation/experiment. (The breaker will be turned back on.)

Step 5: Conduct the experiment and collect data. (The breaker is turned on and the lights are observed.)

Step 6: Draw conclusions. (The breaker being tripped caused the lights to go out.)

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to list the steps of the scientific method.

What are the steps of the scientific method?

a) Identify the problem in a statement that expresses the general purpose of the research.
b) Investigate earlier research to identify alternative explanations or solutions to the problem.
c) Formulate a hypothesis about the anticipated outcome of the research.
d) Design the experiment.
e) Conduct the experiment and collect data.
f) Analyze the data and draw conclusions about the success of the experiment in terms of the hypothesis.

2. Ask students why following the scientific method is important.

Why is it important to follow the scientific method?

a) The scientific method provides a logical approach to solving a problem.
b) The scientific method helps researchers look objectively at their research.
c) The scientific method allows experiments to be repeated by other researchers (replication), which is necessary to establish the validity of the experiment.

3. Ask students why it is important for businesses to keep a financial record book (to be able to analyze the business, to show weak areas, and to provide a credible record for the IRS). Laboratory notebooks are like financial record books; they are kept to analyze experiments, show weak areas, and provide a credible record for other professionals. Relate recording research to the activities of farmers or businesspeople who must keep an accurate record of his or her operation.

What information should a laboratory notebook include?

a) Cover that identifies the subject of the research
b) Table of contents
c) Laboratory sheets
   1) Title of the experiment, date, and name(s) of the investigator(s) of the experiment
   2) Brief description of the purpose of the experiment
   3) List of materials needed
   4) Procedures for the experiment
   5) A record of the results of the experiment, including data and observations
   6) Conclusions drawn from the research

F. Other Activities

G. Conclusion

The scientific method has been used to guide the research process for centuries. It provides a clear, logical method for investigating phenomena. The way a researcher approaches a problem is critical to the success of the investigation. The approach must be documented in a laboratory notebook. This documentation is important for many reasons, including the fact that it often is needed to prove ownership of research.

H. Answers to Activity Sheet

AS 1.1

1. (Answers will vary.) The use of an ultraviolet light is a better method of preventing culture media contamination than the use of either 70 percent alcohol or a 10 percent bleach solution.

2. (Answers will vary.) Exposure to the air, the procedure, the temperature, etc.

3. The sterile cotton swab or ball placed in the petri dish without being swabbed

I. Answers to the Evaluation

1. d
2. b
3. Problem statement
4. Hypothesis
5. a) 5 d) 1
   b) 6 e) 4
   c) 3 f) 2

UNIT III: BASIC LABORATORY SKILLS Name _____

Lesson 1: The Scientific Method Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. The scientific method is important to biotechnology researchers because it:

   a. Guarantees that the research will be successful.
   b. Has always been used in scientific research.
   c. Provides a biased view of a research effort.
   d. Gives a logical structure to a research effort.

2. Which of the following is <u>not</u> necessarily a part of a laboratory sheet?

   a. Date of research and names of researchers
   b. Table of contents
   c. Description of experimental procedures
   d. Observations

Fill in the blanks with the most appropriate term(s).

3. A statement that describes the general purpose of the research is called the _____.

4. A focused and detailed statement that indicates the anticipated outcome of the research is called the _____.

Number the six steps of the scientific method in the order in which they occur.

5. _____ a. Conduct the experiment and collect data.

   _____ b. Draw conclusions.

   _____ c. Formulate a hypothesis.

   _____ d. Identify the problem.

   _____ e. Design the experiment.

   _____ f. Investigate earlier research.

Using the Scientific Method

Objective: Perform a simple experiment following the principles of the scientific method and document the experiment in a laboratory notebook.

Materials and Equipment:

4 petri dishes or test tubes purchased with sterile culture media
4 sterile cotton swabs or balls
4 pairs of sterile latex gloves or regular latex gloves dipped in alcohol and allowed to dry
4 strips of Parafilm™ or clear tape
2 strips of sterile first aid gauze
1 bottle of a 10 percent bleach solution
1 ultraviolet light
Clean table or countertop divided into three sections by cardboard dividers taped to the surface

To sucessfully complete genetic manipulation techniques, a microbe-free or aseptic environment is necessary. This aseptic environment can be obtained in several ways, including wiping the surfaces with 70 percent alcohol, wiping the surfaces with a 10 percent bleach solution, or exposing the surfaces to an ultraviolet light. This experiment will determine which of these methods is most effective.

Procedure:

1. Your teacher will divide the class into groups. Before beginning the experiment, record the title of this experiment, the date, and the names of the members of your group on a lab sheet.
2. Write down a brief statement of the purpose of the experiment.
3. List the materials that will be used on your lab sheet.
4. Carry out the experiment. As you do, write down the steps of the procedure in the form of a descriptive paragraph.
5. Label each section of the table to match one of the treatment methods being used.
6. Using a piece of sterile gauze, wipe down one section of the table with 70 percent alcohol.
7. Using a new piece of sterile gauze, wipe down another section of the table with 10 percent bleach solution.
8. After these sections of the table have completely dried, put on sterile latex gloves and swab one section with a sterile cotton swab or ball.
9. Place the swab immediately into a petri dish or test tube containing sterile culture media. Seal the container with Parafilm™ or tape.
10. Label the petri dish or test tube with the name of the section of the table.
11. Repeat this process for the second section of the table using a new pair of sterile gloves.
12. Expose the third section of the table to an ultraviolet light overnight.

13. Immediately after the light is turned off, swab the table area using the same procedure as in steps 8 and 9.

14. Using a new pair of sterile gloves, open the fourth petri dish or test tube and place a sterile cotton swab or ball in it. Seal the lid in the same way as the others.

15. Keep the petri dishes or test tubes in a warm place for one to three weeks. Observe the results and record them daily on the laboratory sheet.

16. At the end of the period, write down the conclusions drawn from the experiment.

Key Questions:

1. What is a possible hypothesis for this experiment?

2. What factors were kept equal for all samples?

3. What is the control in this experiment?

Title:_____

Date:_____

Name(s):_____

Purpose:

Materials Needed:

Procedure:

Results:

Conclusions:

UNIT III: BASIC LABORATORY SKILLS

Lesson 2: Laboratory Equipment and Techniques

Competency/Objective: Demonstrate the proper use of laboratory equipment and techniques.

Study Questions

1. **What equipment is commonly used in a biotechnology laboratory?**
2. **What are the parts of a microscope, and how are they used?**
3. **What are the procedures for manipulating microscopic specimens?**
4. **What is meant by aseptic techniques?**
5. **Why is it important to follow aseptic techniques?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit III.
2. Activity Sheet
   a) AS 2.1: Parts of a Microscope

UNIT III - BASIC LABORATORY SKILLS

Lesson 2: Laboratory Equipment and Techniques

TEACHING PROCEDURES

A. Review

Researchers must be familiar with biotechnology laboratory equipment to select the proper experimental methods to use to accept or reject a hypothesis using the scientific method discussed in Lesson 1. This lesson reviews equipment commonly found in a laboratory, the parts and use of the microscope, and aseptic techniques.

B. Motivation

Swab a school drinking fountain or a tabletop with a sterile cotton ball or cotton swab. Place this swab in a petri dish containing autoclaved agar in an incubator or another warm space (such as in a greenhouse out of direct sun, in a 1' × 1' cardboard box heated by 10 watt bulb, or on a shelf a foot away from a warm radiator). The resulting bacterial growth will appear overnight, displaying the need for aseptic techniques. Use an autoclave or pressure cooker to kill the bacteria before disposal.

C. Assignment

D. Supervised Study

E. Discussion

1. Discuss the various pieces of equipment commonly used in a laboratory. Display any available laboratory equipment. Use pictures in catalogs from lab equipment suppliers (such as Fisher Scientific) to show equipment that is not available.

   What equipment is commonly used in a biotechnology laboratory?

   a) Pipettor - used to measure and transfer amounts of liquid smaller than one milliliter (ml)
   b) Plastic ware and glassware
      1) Pipette tips
      2) Test tubes
      3) Centrifuge tubes
      4) Petri dishes
      5) Beakers
      6) Flasks
      7) Test tubes
   c) Autoclave - used to sterilize glassware, plastic ware, etc.
   d) Fume hood - vents air to the outside, getting rid of fumes
   e) Incubator - used for tissue culture and the propagation of bacteria
   f) Electrophoresis unit - uses an electric current to separate DNA fragments by size
   g) Transilluminator - used to view an electrophoresis gel
   h) PCR equipment - may be hot water baths or a thermocycler; used to cause the replication of DNA
   i) Microcentrifuge - separates solids from liquids
   j) Vortex - mixes a solid with a liquid in test tubes
   k) Microscope - used to enlarge and view microorganisms or specimens not visible to the naked eye

2. Display an actual microscope and identify each part. Have students complete AS 2.1.

What are the parts of a microscope, and how are they used?

a) Ocular or eyepiece - initial point for viewing a specimen that contains the first lens system, usually magnifying 10 times
b) Objective - second lens system that magnifies the image and projects it up to the ocular
c) Nosepiece - rotating piece that holds the objectives
d) Body tube - holds the ocular and objective the correct distance apart
e) Arm - curved support connecting the body tube and base
f) Base - stand on which the microscope rests
g) Stage - place where the specimen is placed for observation
h) Disc diaphragm - contains a series of openings of different sizes that control the amount of light shining on the specimen
i) Light source - usually a mirror or electric lamp
j) Condenser - focuses light from the lamp on the specimen
k) Coarse adjustment - Large dial, used first to focus the low-power objective
l) Fine adjustment - Small dial, used to refine the focus or to focus the high power objective

3. Ask students who have used a microscope to recall how to view a specimen slide under a microscope. Demonstrate and explain the procedures used when viewing specimens.

What are the procedures for manipulating microscopic specimens?

a) The specimen must be mounted on a glass slide, with a drop of water added for a wet mount.
b) A cover slip is usually placed on top of the specimen.
c) Some specimens may need to be stained.
d) The slide is placed on the stage and secured by the clips.
e) The light source is turned on and adjusted.
f) The low-power objective is selected, and the coarse adjustment is used to focus the image.
g) If needed, the high-power objective is selected and the fine adjustment is used to focus the image by moving the objective up and away from the stage.

4. Ask students why hospital operating rooms are kept sterile. Compare biotechnology techniques such as tissue culture to surgery. Discuss the aseptic techniques used in research in biotechnology.

What is meant by aseptic techniques?

Aseptic techniques are procedures used to create and maintain a working area free of bacteria and other microorganisms that might contaminate delicate experiments.

a) Controlled air movement - The researcher works in an enclosed chamber, which allows the flow of air to be controlled.
b) Disinfection - The work area is disinfected with a 10 percent bleach solution. Then the instruments and work area are sprayed with a 70 percent ethanol solution and allowed to air dry.
c) Scrubbing up - The researcher scrubs his or her hands and arms thoroughly and allows them to air dry. He or she then sprays them with a 70 percent ethanol solution.
d) Sterilization - Researchers use an autoclave to sterilize all materials and instruments. An ultraviolet light kills microorganisms in the work area.

5. Ask students why aseptic techniques are important. Remind students about the motivation for this lesson.

Why is it important to follow aseptic techniques?

Experimental procedures like tissue culture and most DNA analysis techniques require proper aseptic techniques to be successful. Contaminants can disrupt many biotechnology experiments.

F. Other Activities

1. Using a microscope and a prepared slide, have students practice focusing it in the proper manner.

2. Watch a sterile and a nonsterile test tube containing fruit for several days to observe bacterial growth.

G. Conclusion

Many different types of laboratory equipment used in biotechnology have been introduced in this lesson. The microscope has been examined in detail, since it is a common tool used in examining microorganisms. The importance of aseptic techniques has been described as well. These basic laboratory skills are important, and all researchers must master them.

H. Answers to Activity Sheet

AS 2.1

1. Ocular or eyepiece
2. Body tube
3. Nosepiece
4. Objective
5. Stage
6. Disc diaphragm
7. Condenser
8. Arm
9. Fine adjustment
10. Coarse adjustment
11. Light source
12. Base

I. Answers to Evaluation

1. a
2. c
3. c
4. b
5. d
6. a
7. d

8. Students may list any two of the following: controlled air movement, disinfection, scrubbing up, or sterilization.

9. Experimental procedures like tissue culture and most DNA analysis techniques require proper aseptic techniques to be successful. Contaminants can disrupt many biotechnology experiments.

UNIT III: BASIC LABORATORY SKILLS Name _____

Lesson 2: Laboratory Equipment and Techniques Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. The lens system that is found at the top end of the body tube and normally magnifies 10 times is called the:

   a. Ocular.
   b. Objective.
   c. Disc diaphragm.
   d. Arm.

2. The part of a microscope that controls the amount of light placed on the specimen is called the:

   a. Ocular.
   b. Objective.
   c. Disc diaphragm.
   d. Coarse adjustment.

3. Which of the following should be used to adjust the high-power objective?

   a. Ocular
   b. Objective
   c. Fine adjustment
   d. Coarse adjustment

4. Which of the following is <u>not</u> a common piece of biotechnology equipment?

   a. Transilluminator
   b. Electrotransfectionator
   c. Electrophoresis unit
   d. PCR equipment

5. A microcentrifuge is used in the biotechnology laboratory to:

   a. Mix substances in a test tube.
   b. Separate DNA fragments of different sizes.
   c. Increase the quantity of a DNA sample.
   d. Separate solids from liquids.

6. Pipettors are used to:

   a. Measure and transfer amounts of liquid smaller than one milliliter.
   b. Measure and transfer amounts of liquid larger than one milliliter.
   c. Mix substances in a test tube.
   d. Maintain a suitable environment for the propagation of bacteria.

7. Which of the following is <u>not</u> a procedure for manipulating microscopic specimens?

   a. The specimen must be placed on a glass slide.
   b. A light source must be used so that light passes through the specimen.
   c. The low-power objective and the coarse adjustment are used to obtain the initial focus.
   d. The microscope should be refocused using the coarse adjustment and the high-power objective.

Complete the following short answer questions.

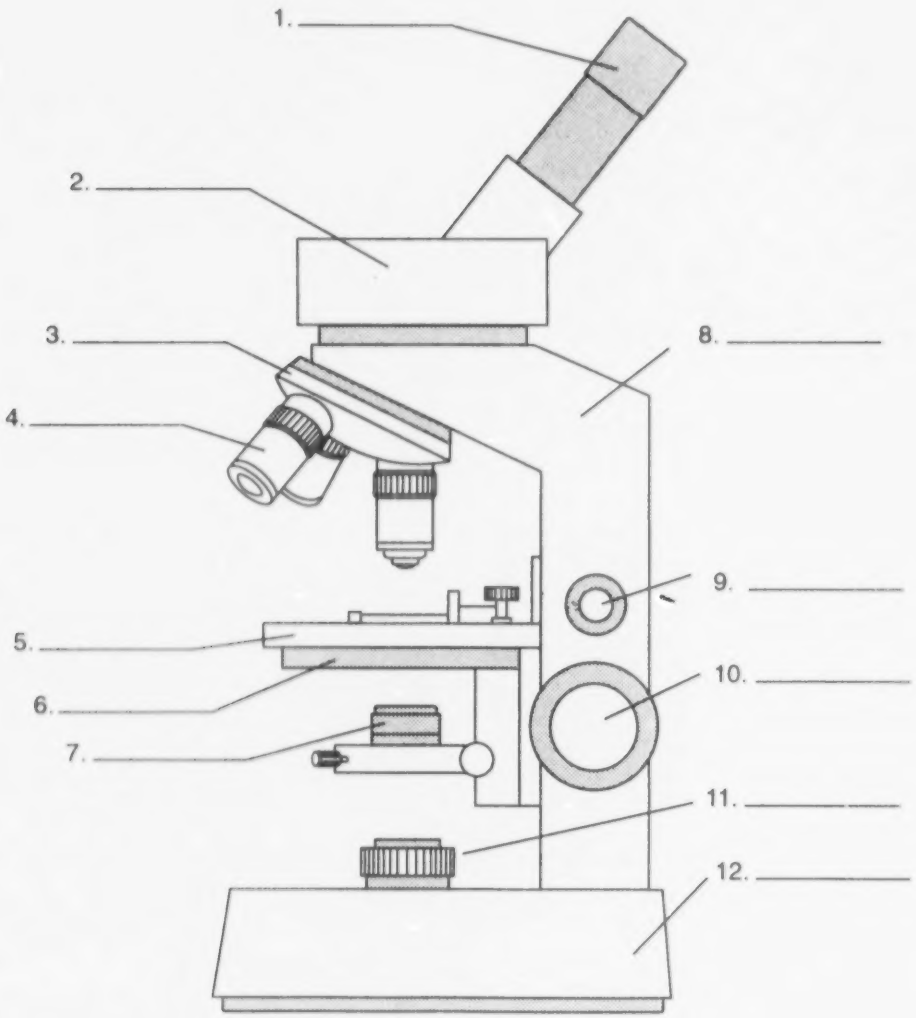
8. What are two aseptic techniques?

9. Why is it important to use aseptic techniques?

Parts of a Microscope

Objective: Identify the parts of a microscope.

Label the parts of the microscope in the spaces provided.



UNIT III - BASIC LABORATORY SKILLS

Lesson 3: Biotechnology Laboratory Safety

Competency/Objective: Explain why safety practices should be followed in the laboratory.

Study Questions

1. **What are some of the common biotechnology laboratory safety concerns?**
2. **How is a spill cleaned up?**
3. **What are the methods for disposing of materials used in biotechnology?**
4. **What procedures should be followed in case of fire?**
5. **What personal protective equipment should be worn in the laboratory?**
6. **What should be done if an injury occurs?**
7. **What ventilation is needed in a laboratory?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit III.
2. Activity Sheet
   a) AS 3.1: Using a Material Safety Data Sheet (MSDS)

UNIT III - BASIC LABORATORY SKILLS

Lesson 3: Biotechnology Laboratory Safety

TEACHING PROCEDURES

A. Review

Lesson 2 discussed some of the equipment used in biotechnology laboratories as well as aseptic techniques to reduce contamination of laboratory experiments. This lesson will examine the topic of laboratory safety. Laboratory safety is always important, especially in biotechnology laboratories. In the late 1970s and early 1980s, laboratories doing genetic manipulation were contained in a nearly sealed environment because of the fear of releasing pathogens, as well as other unknown risks. Today researchers have a much better understanding of the dangers of such research and take necessary precautions when needed. All laboratory research poses some risks that can be addressed by following a detailed safety plan. Laboratory safety is a top priority in every biotechnology laboratory.

B. Motivation

Before students arrive for class, create a "chemical spill" on a countertop in the laboratory that students will notice as they arrive. The chemical spill can simply be water mixed with a few tablespoons of baking soda and a teaspoon of lemon juice. Do not use an actual laboratory chemical or something that will stain the countertop. When students arrive, explain that the spill must be cleaned up, but the correct process must first be determined. Ask them how they would go about cleaning up the spill. Have students speculate as to what types of spills might occur in a biotechnology laboratory.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to list the safety concerns that they would have if they were working in a biotechnology laboratory.

   What are some of the common biotechnology laboratory safety concerns?

   a) Microorganisms - Pathogenic microbes are dangerous because they can cause disease, and even nonpathogenic microorganisms can be harmful in certain cases.
   b) Chemicals
   c) Radioactivity - Researchers must be trained to handle and dispose of radioactive materials safely.
   d) Electrical hazards - Electrophoresis equipment can cause electrical shock.
   e) Physical hazards - Centrifuges can injure fingers, and the ultraviolet light from transilluminators can damage retinas and skin.

2. Ask students to list the types of substances that might be spilled in a biotechnology laboratory (acids, bases, stains, microbe cultures, buffer solutions, etc.). Discuss the clean up procedure and demonstrate the procedure by cleaning up the spill.

   How is a spill cleaned up?

   a) When the spilled chemical is known, the Material Safety Data Sheet (MSDS) outlines the proper clean up procedures.

b) When the substance is an unknown liquid, it should be absorbed using a special spill pillow; the spill pillow should then be disposed of as hazardous waste.
c) If the spill is an unknown solid or powder, it can be gently swept into a glass container and disposed of as hazardous waste.
d) Next, the spill area should be cleaned with a disinfectant and an ethanol solution.

3. Discuss with students the different types of waste generated in a biotechnology laboratory and how wastes should be discarded.

What are the methods for disposing of materials used in biotechnology?

a) All cultures and equipment that come in contact with microbes should be autoclaved or disinfected with hospital-type disinfectants before being thrown away.
b) The MSDS should be followed for chemicals.

4. Ask students to if they know the classroom fire plan. Discuss the procedures to be followed if a fire breaks out.

What procedures should be followed in case of fire?

a) The fire exit plan should be practiced during fire drills and followed when a fire occurs.
b) Everyone should know the location of the fire extinguisher, fire blanket, and fire alarm switch.

5. Ask students to describe the personal protective equipment (PPE) needed for handling pesticides. Compare this list with the PPE needed for most biotechnology laboratories.

What personal protective equipment should be worn in the laboratory?

a) Safety glasses or goggles
b) Disposable latex gloves
c) Lab coat or apron

6. Ask students if they know what to do for various types of injuries.

What should be done if an injury occurs?

a) Simple first-aid procedures, like applying pressure to stop blood loss or flushing skin or eyes with water if they come in contact with chemicals, should be done immediately.
b) In a classroom lab, the instructor should also be notified without delay so that he or she can follow the school procedure for emergencies.

7. Ask students to list some of the airborne hazards found in biotechnology laboratories (gases, fine powders, microbes, etc.).

What ventilation is needed in a laboratory?

a) Fume hoods are used to remove bad odors or harmful vapors from the laboratory and to maintain a sterile environment for certain laboratory procedures.
b) Ventilated lockable chemical storage cabinets prevent the build up of gases that could cause an explosion or a fire.

F. Other Activities

1. Show a video on laboratory safety, such as the video *Beginning Chemistry Laboratory* available from Carolina Biological Supply Company.

2. Use Glo-Germ to show the need for correct manipulation of bacteria and fungi. Glo-Germ is a substance that is visible only under a black light. Place Glo-Germ in a petri dish to represent a culture. Have students perform tasks such as culture transfers, adding nutrients or changing the culture media, or tissue culture procedures. The spread of Glo-Germ to other surfaces represents "contamination" of work areas. If the Glo-Germ is not present on any surfaces, then the students have been successful.

G. Conclusion

Safety in the biotechnology laboratory is critical. Careful, safe working habits help produce successful research results. If chemicals, cultures, or equipment are mishandled, the research is exposed to unnecessary hazards and may fail. Researchers can work safely and effectively if proper precautions are taken in the laboratory.

H. Answers to Activity Sheet

AS 3.1

1. Students may list any five of the following: chemical product and company identification; composition, information on ingredients; hazards identification; first aid measures; fire fighting measures; accidental release measures; handling and storage; exposure controls, personal protection; physical and chemical properties; stability and reactivity; toxicological information; ecological information; disposal considerations; transport information; regulatory information; and other information.

2. In a manner consistent with federal, state, and local regulations

3. Strong oxidizing agents; may form an explosive mixture with flourine or potassium nitrate

4. It is not listed as a carcinogen.

5. Get medical aid. Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes.

6. Odorless to a slightly acetic-like odor

7. Safety glasses with side shields, gloves, protective clothing to prevent skin exposure, and a NIOSH/MSHA-approved air purifying dust or mist respirator

8. It may cause respiratory and digestive tract irritation. It may also cause eye and skin irritation.

I. Answers to Evaluation

1. b
2. d
3. a

4. The fire exit plan should be practiced during fire drills and followed when a fire occurs. Everyone should know the location of the fire extinguisher, fire blanket, and fire alarm switch.

5. Safety glasses or goggles, disposable latex gloves, and a lab coat or apron

6. Spill pillow

7. Flush the area with water and notify the instructor.

8. d
9. c
10. e
11. b
12. a

UNIT III - BASIC LABORATORY SKILLS Name _____

Lesson 3: Biotechnology Laboratory Safety Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What equipment is used in a laboratory for ventilation?

   a. None
   b. Fume hood
   c. Fume cabinet
   d. Open window

2. An MSDS contains important information about:

   a. Radioactive substances.
   b. Specialty laboratory equipment.
   c. Cultures of microorganisms.
   d. Chemical substances.

3. Before microbial cultures are disposed of they should be:

   a. Autoclaved.
   b. Sterilized.
   c. Sealed in an airtight container.
   d. Carefully scrubbed.

Complete the following short answer questions.

4. What procedures should be followed in a laboratory to safeguard against fires?

5. What personal protective equipment (PPE) should be worn in the laboratory?

6. What should be used to clean up an unknown liquid that has spilled?

7. What should be done if acid is spilled on a student's hand in the laboratory?

Match the following hazards with an action in the second column that will help to protect the biotechnology researcher from the hazard.

8.	_____ Physical hazards	a.	Aseptic techniques
9.	_____ Electrical hazards	b.	Following the MSDS
10.	_____ Radioactivity	c.	Careful use of electrophoresis equipment
11.	_____ Chemicals	d.	Careful use of centrifuges and transilluminators
12.	_____ Microorganisms	e.	Special training

Lesson 3: Biotechnology Laboratory Safety Name _____

Using a Material Safety Data Sheet (MSDS)

Objective: Identify important information from an MSDS.

Using the MSDS provided, answer the following questions.

1. What are five of the major sections common to an MSDS sheet?

2. How should the chemical be disposed of, according to the MSDS sheet?

3. With what materials is the chemical incompatible?

4. Is the chemical a known carcinogen?

5. What first aid measures should be taken if the chemical comes in contact with the skin?

6. Does the chemical have an odor?

7. What personal protective equipment should be worn when using the chemical?

8. What are the health effects of this chemical?

Fisher Scientific

Material Safety Data Sheet

Sodium acetate, anhydrous

Section 1 - Chemical Product and Company Identification

MSDS Name:
Sodium acetate, anhydrous

Catalog Numbers:
BP333 1, BP333 500, BP333-1, BP333-500, BP3331, BP333500, S207 10, S20710, S210 2, S210 500, S210-2, S210-3, S210-500, S2102, S2103, S210500, S78228, S782291

Synonyms:
Acetic acid,sodium salt, Sodium acetate

Company Identification:
Fisher Scientific - Fairlawn
Fairlawn, NJ 07410

Company Phone Number:
(201) 796-7100

Emergency Phone Number:
(201) 796-7100

CHEMTREC Phone Number, US:
(800) 424-9300

CHEMTREC Phone Number, Europe:
(202) 483-7616

Section 2 - Composition, Information on Ingredients

CAS#	Chemical Name:	Percent	EINECS/ELINCS
127-09-3	Sodium acetate	100	204-823-8

Hazard Symbols:
Risk Phrases:

Section 3 - Hazards Identification

EMERGENCY OVERVIEW

Appearance: white
Caution! Hygroscopic. May cause respiratory and digestive tract irritation. May cause eye and skin irritation.
Target Organs: None.

Potential Health Effects

Eye:
May cause mild eye irritation.

Skin:
May cause skin irritation.

Ingestion:
May cause irritation of the digestive tract.

Inhalation:
May cause respiratory tract irritation.

Chronic:
Prolonged or repeated skin contact may cause irritation.

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Material Safety Data Sheet

Sodium acetate, anhydrous

Section 4 - First Aid Measures

Eyes:
Flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower lids. Get medical aid.

Skin:
Get medical aid. Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes.

Ingestion:
If victim is conscious and alert, give 2-4 cupfuls of milk or water. Never give anything by mouth to an unconscious person. Get medical aid.

Inhalation:
Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid if cough or other symptoms appear.

Notes to Physician:
None

Antidote:
None reported

Section 5 - Fire Fighting Measures

General Information:
As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear. Dusts at sufficient concentrations can form explosive mixtures with air. Wear appropriate protective clothing to prevent contact with skin and eyes. Wear a self-contained breathing apparatus (SCBA) to prevent contact with thermal decomposition products.

Extinguishing Media:
For small fires, use water spray, dry chemical, carbon dioxide or chemical foam.

Autoignition Temperature:
607°C (1,124.60°F)

Flash Point:

NFPA Rating:
Not published.

Explosion Limits:
Lower: Upper:

Section 6 - Accidental Release Measures

General Information:
Use proper personal protective equipment as indicated in Section 8.

Spills/Leaks:
Vacuum or sweep up material and place into a suitable disposal container. Avoid generating dusty conditions.

Section 7 - Handling and Storage

Handling:
Wash thoroughly after handling. Remove contaminated clothing and wash before reuse. Use with adequate ventilation.

Storage:
Store in a cool, dry, well-ventilated area away from incompatible substances.

Storage Code:
Gray

Material Safety Data Sheet

Sodium acetate, anhydrous

Section 8 - Exposure Controls, Personal Protection

Engineering Controls:
Good general ventilation should be sufficient to control airborne levels.

Exposure Limits

Chemical Name:	ACGIH	NIOSH	OSHA
Sodium acetate	None listed.	None listed.	None listed.

OSHA Vacated PELs

Personal Protective Equipment

Eyes:
Wear safety glasses with side shields.

Skin:
Wear appropriate gloves to prevent skin exposure.

Clothing:
Wear appropriate protective clothing to prevent skin exposure.

Respirators:
A NIOSH/MSHA approved air purifying dust or mist respirator.

Section 9 - Physical and Chemical Properties

Physical State:	Solid
Appearance:	white
Odor:	odorless to slight acetic-like odor
pH:	No information available.
Vapor Pressure:	No information available.
Vapor Density:	No information available.
Evaporation Rate:	No information available.
Viscosity:	No information available.
Boiling Point:	@ 760.00mm Hg
Freezing/Melting Point:	324.00°C
Decomposition Temperature:	No information available.
Solubility:	1190 g/l (20 c)
Specific Gravity/Density:	No information available.
Molecular Formula:	C2H3O2Na
Molecular Weight	82.03

Section 10 - Stability and Reactivity

Chemical Stability:
Stable.

Conditions to Avoid:
Incompatible materials.

Incompatibilities with Other Materials
Strong oxidizing agents. Explosive mixtures may be formed with fluorine or potassium nitrite.

Hazardous Decomposition Products
Carbon monoxide, carbon dioxide, toxic fumes of sodium oxide.

Hazardous Polymerization
Has not been reported.

Section 11 - Toxicological Information

RTECS:
CAS# 127-09-3: AJ4300010.

LD50/LC50:
CAS# 127-09-3:
Oral, mouse: LD50 = 6891 mg/kg
Oral, rat: LD50 = 3530 mg/kg.

Carcinogenicity:
CAS# 127-09-3: Not listed as a carcinogen by ACGIH, IARC, NIOSH, NTP, OSHA, or CA Prop 65.

Epidemiology:
No data

Teratogenicity:
No data

Reproductive:
No data

Mutagenicity
No data

Neurotoxicity
No information reported

Section 12 - Ecological Information

Ecotoxicity:
No information reported
Acute aquatic effects: 96-hour LC50 for fathead minnow: GT 100mg/L, 96-hour LC50 for water flea: GT 1000mg/L.
This chemical has a low potential to affect aquatic organisms.

Environmental:
This chemical is readily biodegradable and is not likely to bioconcentrate.

Physical:
None.

Other:
This chemical has a high biological oxygen demand, and it is expected to cause significant oxygen depletion in aquatic systems.

Section 13 - Disposal Considerations

Dispose of in a manner consistent with federal, state, and local regulations.

RCRA D-Maximum Concentration of Contaminants
None of the components are on this list.

RCRA D Series - Chronic Toxicity Reference Levels
None of the components are on this list.

RCRA F Series Wastes
None of the components are on this list.

RCRA P Series Wastes
None of the components are on this list.

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RCRA U Series Wastes
None of the components are on this list.

RCRA Substances Banned from Land Disposal
None of the components are on this list.

Material Safety Data Sheet

Sodium acetate, anhydrous

Section 14 - Transport Information

	US DOT	IATA	IMO	RID/ADR	Canadian TDG
Shipping Name:	No information available.	No information available.	No information available.	No information available.	No information available.
Hazard Class:					
UN Number:					
Packing Group:					

Section 15 - Regulatory Information

US Federal

TSCA
CAS# 127-09-3 is listed on the TSCA Inventory.

Health and Safety Reporting List
None of the components are on this list.

Chemical Test Rules
None of the components are on this list.

TSCA Section 12b
None of the components are on this list.

TSCA Significant New Use Rule (SNUR)
None of the components are on this list.

CERCLA Reportable Quantities (RQ)
None of the components are on this list.

SARA Threshold Planning Quantities (TPQ)
None of the components are on this list.

SARA Hazard Categories
None of the components are on this list.

SARA Section 313
None of the components are on this list.

Clean Air Act - Hazardous Air Pollutants (HAPs)
None of the components are on this list.

Clean Air Act - Class 1 Ozone Depletors
None of the components are on this list.

Clean Air Act - Class 2 Ozone Depletors
None of the components are on this list.

Clean Water Act - Hazardous Substances
None of the components are on this list.

Clean Water Act - Priority Pollutants
None of the components are on this list.

Clean Water Act - Toxic Pollutants
None of the components are on this list.

OSHA - Highly Hazardous
None of the components are on this list.

US State

Material Safety Data Sheet

Sodium acetate, anhydrous

State Right to Know

California Prop 65

California No Significant Risk Level
No information available.

European/International Regulations

European Labelling in Accordance with EC Directives:
Hazard Symbols:
Risk Phrases:
Safety Phrases: S 24/25 Avoid contact with skin and eyes.

WGK (Water Danger/Protection)
No information available.

Canadian DSL/NDSL
CAS# 127-09-3 is listed on Canada's DSL/NDSL List.

Canadian WHMIS Classifications
This product has a WHMIS classification of D2B.

Canada Ingredient Disclosure List
CAS# 127-09-3 is not listed on Canada's Ingredient Disclosure List.

Exposure Limits

Section 16 - Other Information

Color information has been reworded.
MSDS Creation Date: December 13, 1994
Revision Date: October 23, 1997

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantibility or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no event shall Fisher be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential, or exemplary damages howsoever arising, even if Fisher has been advised of the possibility of such damages.

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UNIT IV: FOUNDATIONS OF GENETIC ENGINEERING

Lesson 1: The Mechanics of Cells and DNA

Competency/Objective: Identify the parts of a cell, including DNA, and their functions.

Study Questions

1. **What are the parts of a cell and their functions?**
2. **What is DNA?**
3. **What is the structure and function of DNA?**
4. **How does DNA replicate?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit IV.
2. Transparency Masters
   a) TM 1.1: The Parts of a Cell
   b) TM 1.2: The Cellular Chain of Command
   c) TM 1.3: DNA Replication
3. Activity Sheet
   a) AS 1.1: Comparing Plant and Animal Cells

UNIT IV: FOUNDATIONS OF GENETIC ENGINEERING

Lesson 1: The Mechanics of Cells and DNA

TEACHING PROCEDURES

A. Introduction

Just as an automobile mechanic must understand the basics of how an engine works, so the biotechnology researcher must understand the cell, its parts, and how they work. This lesson will provide a review of concepts taught in biology and will lay the foundation for future lessons on the manipulation of genetic material.

B. Motivation

1. Use a model of DNA to illustrate its structure. A model can be purchased, or a flat model of DNA can be put together using a series of cards with the base pairs written on them. Students could also hold these cards in the appropriate position to simulate the double helix structure.

2. To observe cell walls in a plant cell, slice a carrot very thinly, so that light can easily be seen through it. Freeze the carrot slices. Take a frozen slice and place it under a microscope. Quickly observe the cell walls as they deteriorate when the cells thaw.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to name as many parts of a cell as they can. Have a student write these on the board. Add any parts that they might have missed. Use TM 1.1 to illustrate the parts. Have students complete AS 1.1.

What are the parts of a cell and their functions?

a) Animal cell
   1) Cell (plasma) membrane - controls movement of materials into and out of the cell
   2) Cytoplasm - the contents of the cell, excluding the nucleus; contains fluid that helps control the movement of substances within the cell and includes the organelles
   3) Mitochondria - powerhouses of the cell; break down nutrients to provide energy
   4) Endoplasmic reticulum - network of membranes that transports materials within the cell; location of the ribosomes
   5) Ribosomes - primary location for protein synthesis
   6) Golgi apparatus - packages protein molecules for movement within and outside the cell
   7) Vacuole - stores water, enzymes, pigments, and other substances
   8) Nucleus - control center for the cell; contains chromosomes
   9) Chromosomes - tightly wrapped pieces of DNA; location of genes
   10) Genes - a segment of DNA on a chromosome that produces a polypeptide (protein) and is responsible for the expression of genetic traits

b) Plant cell - contains all of the structures found in animal cells with two additions
   1) Chloroplasts - contain chlorophyll, which is used in photosynthesis
   2) Cell wall - rigid outer layer that provides support for the plant cell and works collectively with other cells to support the plant

c) Bacteria cell
   1) Cell wall
   2) Cell membrane
   3) Ribosomes
   4) Nucleoid region - chromosomal material not contained within a nucleus
   5) Plasmid - small circular piece of DNA that codes for specific traits and replicates independently of chromosomal DNA; normally contains only a few genes

2. Ask a student to look up the definition of DNA, or deoxyribonucleic acid, in a dictionary or a CD-ROM encyclopedia.

What is DNA?

a) DNA (deoxyribonucleic acid) is the genetic material of the cell composed of small chemical units called nucleotides, which consist of three parts.
   1) A phosphate group
   2) A sugar (called deoxyribose) unit
   3) One of four nitrogen base units (adenine, guanine, thymine, and cytosine)
b) A single strand of DNA may contain more than 100 million base pairs.

3. Ask students to list as many words on the board as they can that describe what a DNA molecule looks like. Use TM 1.2 to illustrate the structure of DNA.

What is the structure and function of DNA?

a) Structure
   1) Two strands of nucleic acid are intertwined in a double helix structure that looks like a twisted or spiraling ladder.
   2) The phosphate and sugar units form the sides of the ladder, while the nitrogen base units form the rungs.
   3) The base units are found in one of two bonding arrangements, adenine bonded to thymine or guanine bonded to cytosine; hydrogen bonds join the base units.
b) Function
   1) DNA determines what types of proteins to build in protein synthesis.
      (a) DNA functions in sections called codons, which are sets of three nucleotides that code for one of the twenty amino acids.
      (b) These amino acids are then linked together to form polypeptides.
      (c) Two or more polypeptides are linked together to form a protein.
   2) In DNA replication, DNA makes a copy of itself to pass on its code to new cells formed by cell division.

4. Using TM 1.3, ask students why DNA needs to replicate. Explain that DNA must replicate, or each time a cell divided, it would lose half its DNA. Next, have students explain how DNA replication takes place.

How does DNA replicate?

a) A protein made by the cell binds to a place on the DNA called the origin.
b) An enzyme begins to break the hydrogen bonds that hold the two strands of the helix together, causing the double helix to "unzip."
c) A complex enzyme (DNA polymerase) binds to each DNA strand segment and begins to add a new base unit to the strand; the added base must be compatible with the base on the parent DNA strand.
d) Another enzyme then bonds the new nucleotides with the parent DNA strand.
e) Each DNA molecule now consists of one parent strand and one newly formed strand.

F. Other Activities

1. Have students use cardboard puzzle pieces made to look like bases to show how DNA replicates.

2. Have students research and present a report about the discovery of the structure of DNA by Watson and Crick.

G. Conclusion

Plant, animal, and bacteria cells are all different in some respects. However, they all contain at least one chromosome, and therefore they contain DNA. The DNA in a plant, animal, or bacteria cell is essentially the same except for the base pair sequence it contains. This similarity of DNA makes the manipulation and transfer of DNA between different life-forms possible. If the structure or function of plant DNA was different from animal DNA, then DNA from a plant could not be spliced into the DNA of an animal. A clear understanding of the makeup of cells and a working knowledge of the structure and function of DNA is necessary to understand genetic manipulation.

H. Answers to the Activity Sheet

Student pictures will vary, but they should show that the students observed some parts of the cells.

I. Answers to the Evaluation

1. j
2. k
3. g
4. e
5. c
6. f
7. l
8. a
9. b
10. h
11. i
12. d
13. a
14. d
15. b

16. The steps in the replication of DNA are as follows:

- A protein binds to a place on the DNA called the origin.
- An enzyme begins to break the hydrogen bonds that hold the two strands of DNA together, unzipping the double helix.
- As the DNA strands are being unzipped, a complex enzyme (DNA polymerase) binds to each DNA strand segment and begins to add a new base unit to the strand. The added base must be compatible with the base on the parent DNA strand.
- Another enzyme then bonds the new nucleotides with the parent DNA strand.

UNIT IV: FOUNDATIONS OF GENETIC ENGINEERING Name _____

Lesson 1: The Mechanics of Cells and DNA Date _____

EVALUATION

Match the correct function on the right to the cell part on the left by writing the letters in the blanks.

1. _____ Cell wall
2. _____ Cell membrane
3. _____ Cytoplasm
4. _____ Mitochondria
5. _____ Endoplasmic reticulum
6. _____ Ribosomes
7. _____ Golgi apparatus
8. _____ Vacuole
9. _____ Plasmid
10. _____ Nucleus
11. _____ Chromosome
12. _____ Gene

a. Stores water, enzymes, pigments and other substances
b. Small circular piece of DNA that contains a few genes
c. A membrane that transports molecules
d. Segment of DNA that is responsible for the expression of a trait
e. Powerhouse of the cell
f. Primary location for protein synthesis
g. Contents of the cell, excluding the nucleus
h. Control center for the cell
i. Location of genes
j. Provides support for plant cells
k. Controls the movement of materials into and out of the cell
l. Packages protein molecules for movement within and outside the cell

Circle the letter that corresponds to the best answer.

13. The unit of a DNA molecule that contains the code for building proteins is the:

    a. Nitrogen base unit.
    b. Phosphate unit.
    c. Sugar unit.
    d. Potassium unit.

14. When examining the structure of DNA, which of the following bonding arrangements is found in the DNA molecule?

    a. Guanine bonded to thymine
    b. Cytosine bonded to thymine
    c. Adenine bonded to cytosine
    d. Guanine bonded to cytosine

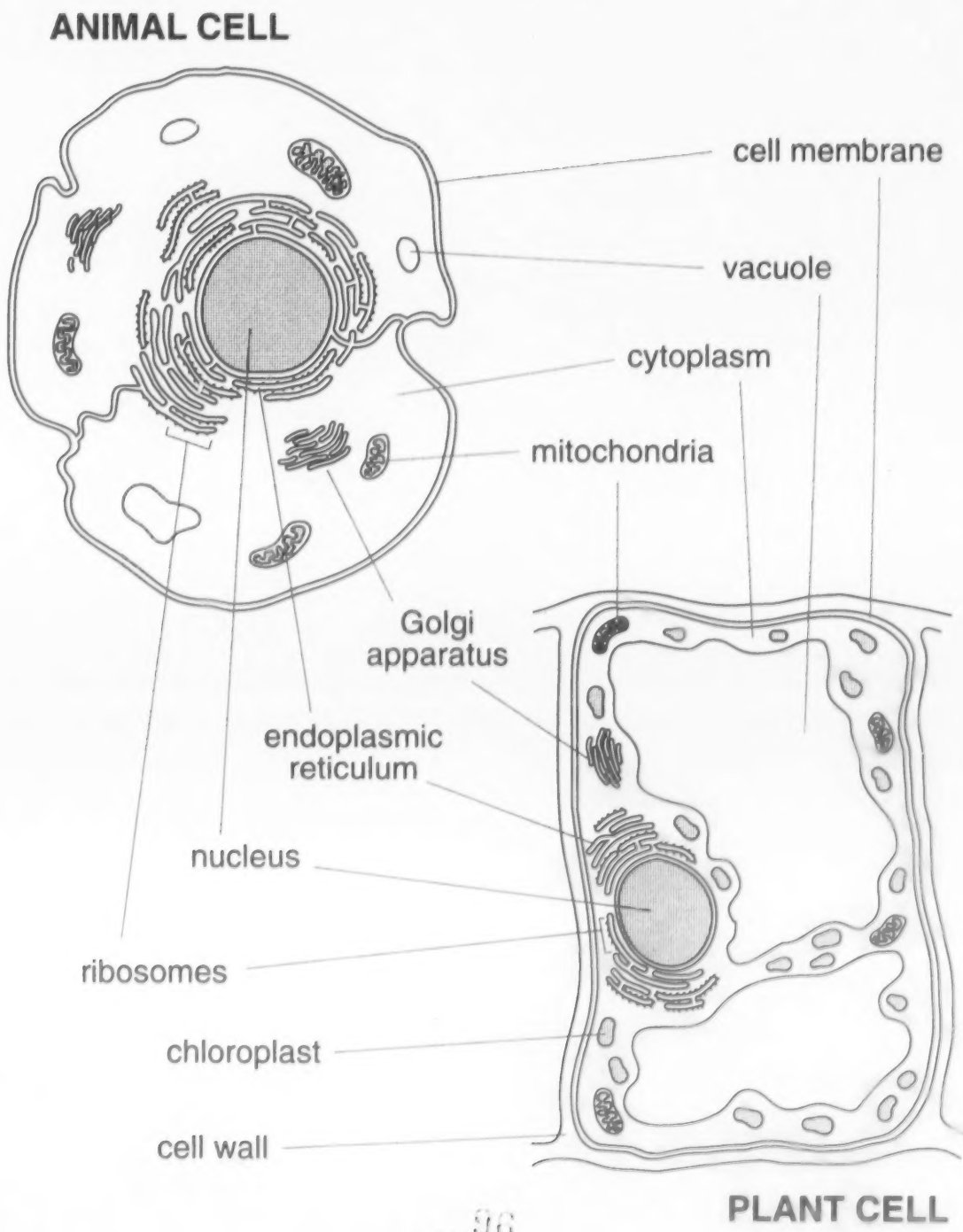
15. A codon is a:

a. Segment of DNA that is responsible for the expression of a trait.
b. Segment of DNA that is three base pairs long and codes for a specific amino acid.
c. Segment of DNA that codes for one of twenty polypeptides.
d. Segment of DNA that contains no base units.

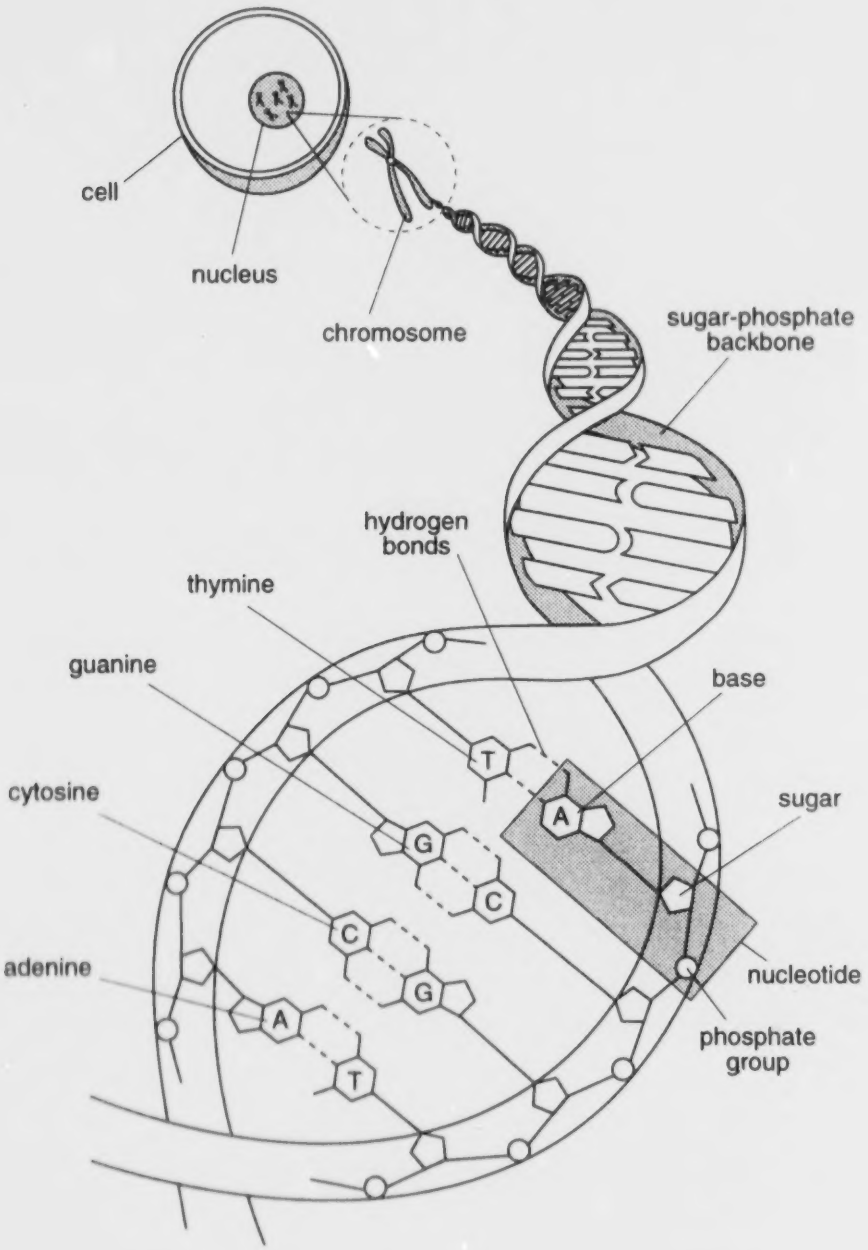
Complete the following short answer question.

16. What are the steps in DNA replication?

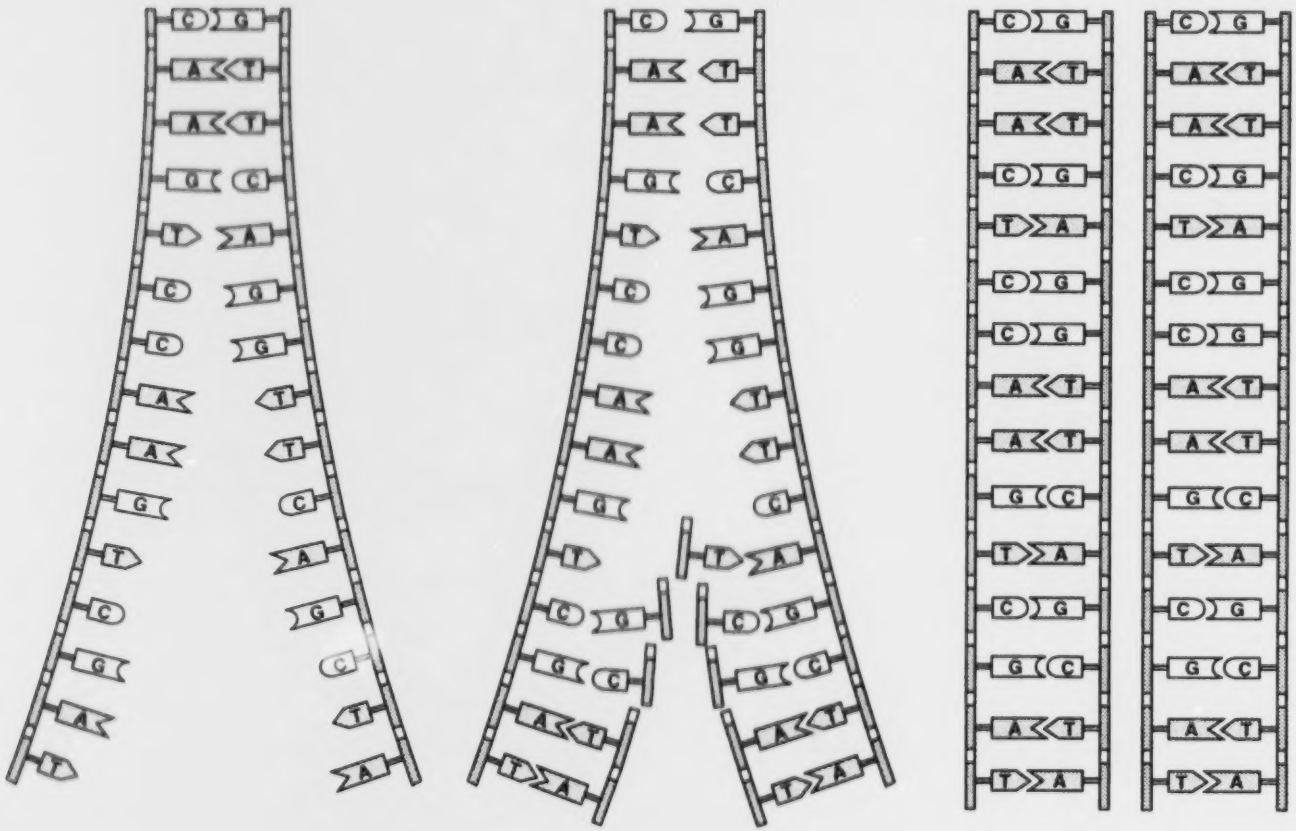
The Parts of a Cell



The Cellular Chain of Command



DNA Replication



Comparing Plant and Animal Cells

Objective: Identify the parts of plant and animal cells.

Materials and Equipment:

Microscope
2 glass slides
2 cover slips
Onion
Toothpicks
0.9 percent NaCl
Methylene blue

Procedure:

A. Red or Purple Onion Cells

1. Remove a paper thin section of an onion peel. Cut out a small piece about the size of a penny. Place this tissue sample on a clean glass slide. Add a drop of water and carefully place a cover slip over the specimen. **Gently** press out any air bubbles.

2. Examine the tissue using the low-power objective and then the high-power objective. Look for the nucleus, nuclear membrane, cytoplasm, and cell wall.

3. Draw a picture of one of the onion cells and label the cell parts that you observed.

B. Human Epithelial Cells

1. Carefully scrape the inside of your mouth with the flattened end of a toothpick. Place the scrapings in a drop of 0.9 percent NaCl on a clean glass slide. Repeat the scraping procedure four times and then place a cover slip over the specimens.

2. Add a drop of methylene blue to one edge of the cover slip. To pull the stain across the specimen, use a paper towel to begin absorbing liquid at the edge of the cover slip opposite the stain. Continue until the excess stain has been removed.

3. Examine the cells using the low- and high-power objectives. Draw and label the parts of the cells that you observe.

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 2: Cell Reproduction and Genetics

Competency/Objective: Explain how cells reproduce.

Study Questions

1. **What is mitosis?**
2. **What is meiosis?**
3. **How do mitosis and meiosis differ?**
4. **What are dominant and recessive genes?**
5. **What are homozygous and heterozygous gene pairs?**
6. **What are genotypes and phenotypes?**
7. **What are mutations?**

References

1. *Biotechnology:Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit IV.
2. Transparency Masters
   a) TM 2.1: Mitosis
   b) TM 2.2: Meiosis
3. Activity Sheet
   a) AS 2.1: Mitosis and Meiosis

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 2: Cell Reproduction and Genetics

TEACHING PROCEDURES

A. Review

In the last lesson, the cell and its components were examined in some detail. This lesson focuses on the two ways in which cells reproduce and how this reproduction can pass on genetic information and the traits seen in the organism's offspring.

B. Motivation

When discussing cell reproduction, the obvious question to ask is why body cells need to reproduce at all. If a body cell can grow and get bigger, why does it need to reproduce itself? Think for a moment about a large car factory. Why do manufacturers like General Motors or Ford have different factories in the Midwest? Why not one big factory?

Several reasons exist for having many factories or many cells. First, the managers of the factory (the nucleus of the cell) can only control a limited workload. The operations of the factory (the making of proteins in the cell) cannot increase above the capacity that the management (cell nucleus) can handle. Another reason for having more than one is so that the supply and export of products is not slowed. The larger a factory gets, the more raw materials it demands (just as the larger a cell gets, the more nutrients, oxygen, and other raw materials it demands). At the same time, the export of products also increases, and these two factors slow the movement of raw materials and products into and out of the factory (cell).

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students if they know how hair, fingernails, skin, or muscles grow. Use TM 2.1 to show the stages of mitosis and how tissues grow.

What is mitosis?

a) Mitosis is a type of cell division in which somatic cells divide and form two new cells; each new cell contains the same number of paired chromosomes as the parent cell, or two complete sets of chromosomes (a diploid number of chromosomes).

b) Stages of mitosis (Hint: Remember PMAT.)

1) Prophase

(a) Chromosomes coil and condense to form a double-stranded structure consisting of two paired chromatids connected at a body called a centromere.

(b) The nuclear membrane dissolves gradually.

(c) A network of microtubules begins forming around centrioles, which start to move to opposite ends of the cell; the network of microtubules is called a spindle.

(d) Spindle fibers extend out from the centrioles toward the center of the cell.

2) Metaphase

(a) Chromosomal units move to the center of the cell and form a line between the two poles.

(b) Each spindle fiber attaches to a centromere.

3) Anaphase
   (a) The centromeres break, allowing the spindle fibers to pull apart the chromatids.
   (b) The chromosomes move toward opposite poles of the cell.
   (c) The poles move farther apart, elongating the cell.
   (d) At the end of anaphase, the two poles each have a complete set of chromosomes.
4) Telophase
   (a) In animal cells, the cell membrane pinches together, dividing the cell into two cells.
   (b) In plant cells, a cell plate forms in the middle of the cell and begins to divide it into two cells; a cell membrane forms on both sides of the cell plate, and the cell plate changes to a cell wall.
   (c) Nuclear membranes develop in the daughter cells.
   (d) The chromosomes uncoil and lose their distinct outlines.

2. Ask students how sex cells divide. Use TM 2.2 to show the stages of meiosis. Have students complete AS 2.1. When doing the activity, make sure to observe each phase before allowing students to move on to the next one. The instructor may want to make up a poster showing the different phases so that students can use it as a model.

What is meiosis?

a) Meiosis is a type of cell division that produces gametes (sex cells). It has two phases of cell division, producing four gametes. The gametes contain half the number of chromosomes found in the parent cell, or a single set of chromosomes, and are referred to as haploid cells.
b) Meiosis I
   1) Prophase I
      (a) Homologous chromosomes pair together and form a tetrad, a grouping of four chromatids side by side.
      (b) Nonpaired chromatids may exchange segments in a process called "crossing over."
      (c) The centrioles move apart and the spindle forms.
      (d) The nuclear membrane dissolves.
   2) Metaphase I
      (a) Homologous chromosomes line up in the center of the cell.
      (b) The spindle fiber ends attach to centromeres.
   3) Anaphase I - Homologous chromosomes separate and are pulled to different poles.
   4) Telophase I
      (a) The cell plate and/or cell membrane forms, creating two haploid daughter cells.
      (b) Nuclear membranes form.
c) Meiosis II
   1) Prophase II
      (a) The spindle fibers develop.
      (b) Paired chromatids move to the center of the cell.
   2) Metaphase II
      (a) The chromosomal units line up in a row between the two poles.
      (b) They become attached to the spindle fibers.
   3) Anaphase II - Chromatids separate and move toward opposite poles.
   4) Telophase II
      (a) The center of each cell closes off with the formation of a cell membrane or cell plate.
      (b) Nuclei form.
      (c) Chromosomes uncoil.

3. Have students compare mitosis and meiosis and list the differences.

How do mitosis and meiosis differ?

a) Mitosis produces two cells from one parent cell, while meiosis produces four cells from one parent cell.
b) Mitosis produces diploid somatic cells, while meiosis produces haploid gametes.
c) Mitosis produces two identical cells, and meiosis produces four nonidentical cells.
    1) During mitosis, chromosomes contribute an identical chromosome to each daughter cell.
    2) In meiosis, homologous chromosomes split and contribute nonidentical chromosomes to each daughter cell.
d) Meiosis allows genes to cross over, while mitosis does not.

4. Ask students to define the word dominant. Relate this definition to dominant and recessive genes.

What are dominant and recessive genes?

a) Chromosomes work in pairs.
b) Each chromosome has a homologous chromosome that has genes that code for the same information but somewhat differently.
c) Each gene in a gene pair is either dominant or recessive.
d) Dominant genes are expressed; they mask the expression of a recessive gene.
e) Recessive genes are genes that are not expressed, or apparent in the traits of the animal.

5. Ask students to define the terms homozygous and heterozygous.

What are homozygous and heterozygous gene pairs?

a) Either of the two possible expressions of a gene or multiple genes that code for a specific trait is called an allele.
b) An organism with two dominant alleles or two recessive alleles is homozygous for that specific trait; they are either homozygous dominant or homozygous recessive.
c) An organism with one dominant allele and one recessive allele is heterozygous for that trait.

6. Have students explain and give examples of a genotype and a phenotype.

What are genotypes and phenotypes?

a) Genotype - The specific combination of alleles for a trait.
b) Phenotype - The appearance or expression of a trait as determined by the genotype.

7. Ask student if they believe that all mutations are bad. Point out that mutations such as seedless grapes and oranges are not harmful.

What are mutations?

a) Mutations are alterations in the nucleotide sequence found in a DNA molecule; they may be from the insertion, deletion, or miscoding of a base unit during replication.
b) Mutations can occur during replication in mitosis or meiosis.
    1) Mutations during mitosis are not inheritable; they affect the daughter cell and any cells descending from it.
    2) Mutations prior to meiosis are passed on to an organism's offspring if the mutant gamete is fertilized.

F. Other Activities

Review the use of Punnet squares to further discuss genotype and phenotype.

G. Conclusion

An understanding of cell reproduction and the basic genetic concepts discussed in this lesson suggests how genetic manipulation must be done. To add a gene to an entire plant or animal, genetic manipulation must be done before or during meiosis. Gene interaction is quite complex, and genetic manipulation is even more complex.

H. Answers to Activity Sheet

AS 2.1

1. a. Mitosis produces two cells from one parent cell, while meiosis produces four cells from one parent cell.
   b. Mitosis produces diploid somatic cells, while meiosis produces haploid gametes.
   c. Mitosis produces two identical cells, and meiosis produces four nonidentical cells.
   d. Meiosis allows genes to cross over, while mitosis does not.

2. In meiosis I, homologous chromosomes are separated, and a double-stranded chromosomal unit is passed on to the new cells. In meiosis II, the chromatids split apart, with each new cell receiving one chromosome.

I. Answers to the Evaluation

1. a
2. d
3. b
4. a
5. c

6. Mutations are alterations in the nucleotide sequence found in a DNA molecule; they may be from the insertion, deletion, or miscoding of a base unit during replication.

7. a) Prophase
   b) Metaphase
   c) Anaphase
   d) Telophase

8. Students may list any two of the following:

   - Mitosis produces two cells from one parent cell, while meiosis produces four cells from one parent cell.
   - Mitosis produces diploid somatic cells, while meiosis produces haploid gametes.
   - Mitosis produces two identical cells, and meiosis produces four nonidentical cells.
   - Meiosis allows genes to cross over, while mitosis does not.

 Name _____

Lesson 2: Cell Reproduction and Genetics Date _____

EVALUATION

Circle the letter that corresponds with the best answer.

1. Meiosis can be defined as a type of cell division in which:

   a. Gametes are produced.
   b. Somatic cells are produced.
   c. Two identical cells are produced.
   d. Diploid cells are produced.

2. One difference between animal and plant cells during the last phase of mitosis is that in animal cells the cell membrane pinches in to divide the cell, while in plant cells:

   a. Cell membranes do not exist.
   b. The cell membrane grows out of the center of the cell, dividing it.
   c. The nuclear wall grows to divide the cell.
   d. The cell plate grows to divide the cell.

3. What is the term used to describe when chromosomes exchange segments during meiosis?

   a. Haploid exchange
   b. Crossing over
   c. Centromere replication
   d. Mutation

4. If a plant has a recessive allele for a dwarf plant and a dominant allele for a tall plant, how tall would the plant be?

   a. Tall
   b. Short
   c. Medium height
   d. It is impossible to tell how tall it will be.

5. What is the appearance or expression of a trait in an organism called?

   a. Chromotype
   b. Genotype
   c. Phenotype
   d. Heterozygous

Complete the following short answer questions.

6. What are mutations?

7. What are the four stages of mitosis, in the order in which they occur?

   a.

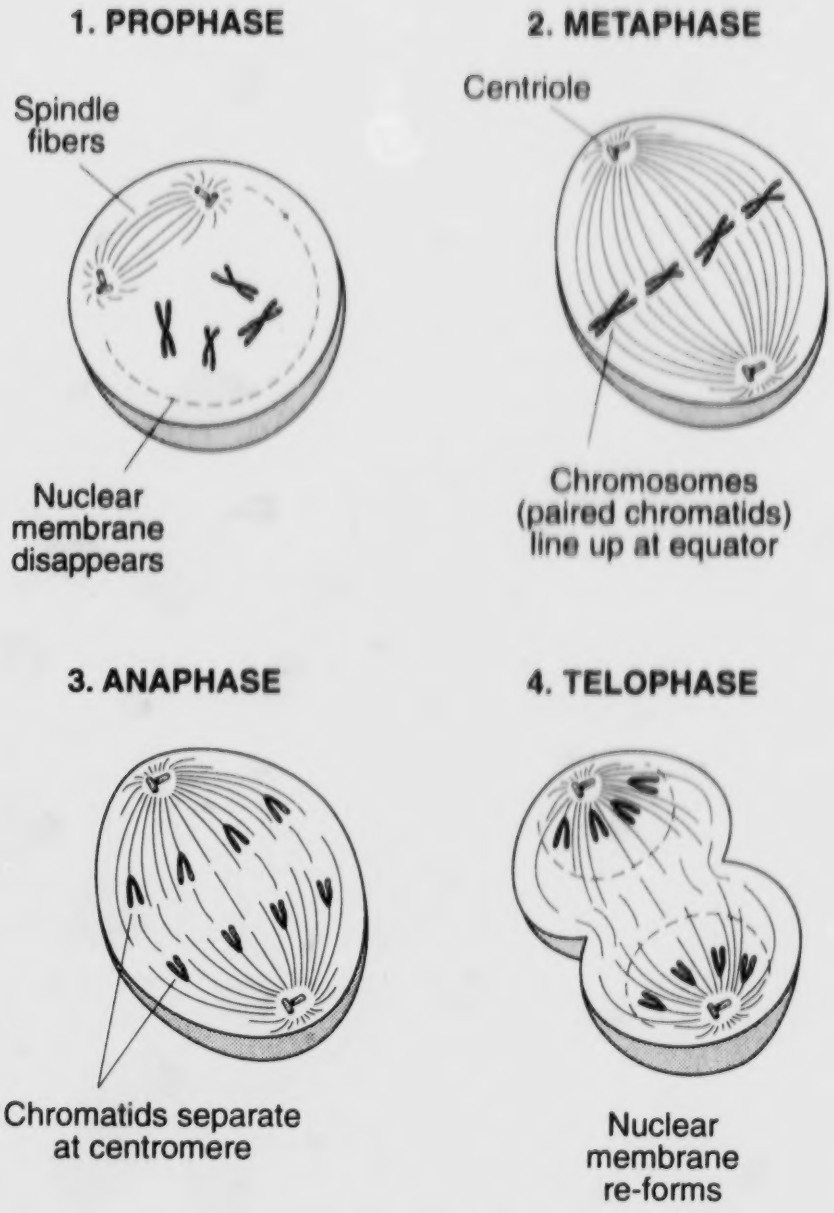
   b.

   c.

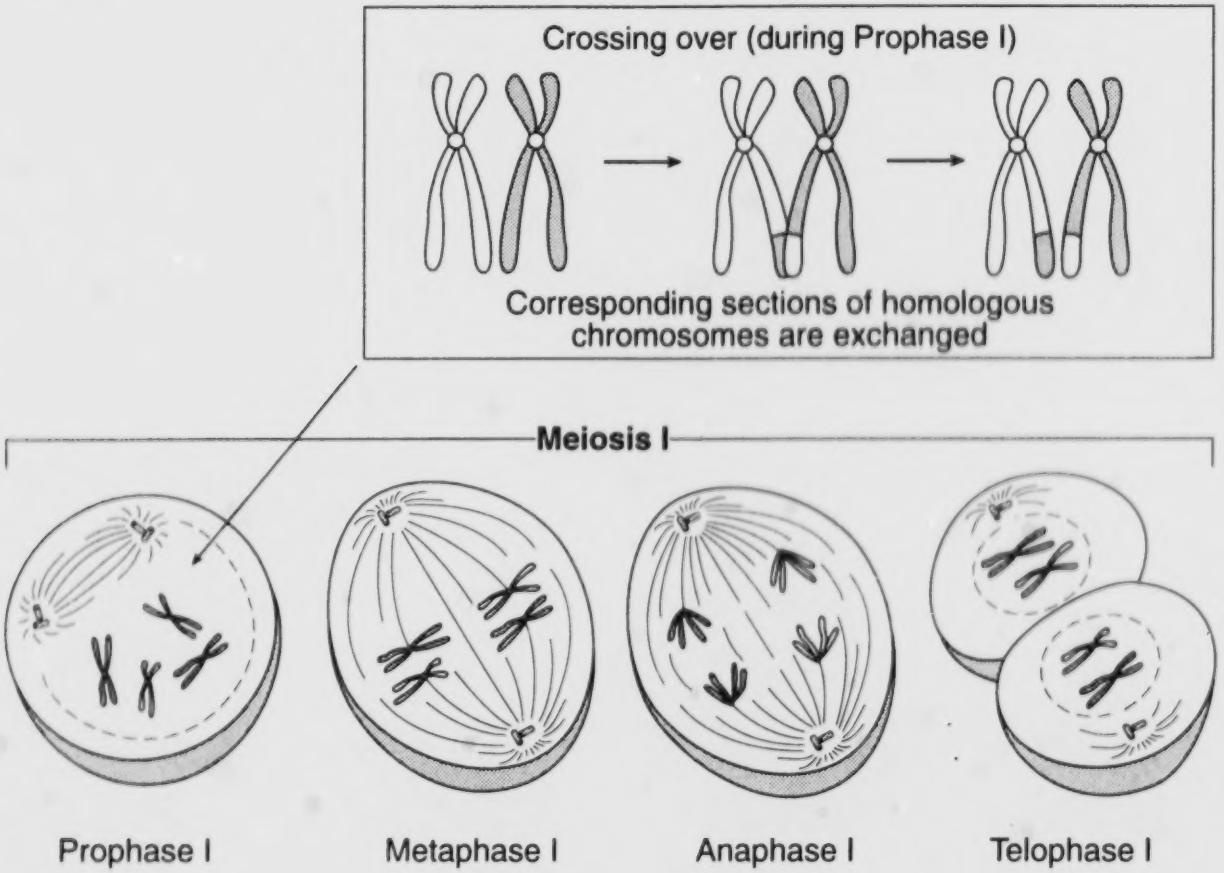
   d.

8. What are two ways in which mitosis and meiosis differ?

Mitosis


1. PROPHASE
Spindle fibers
Nuclear membrane disappears
2. METAPHASE
Centriole
Chromosomes (paired chromatids) line up at equator
3. ANAPHASE
Chromatids separate at centromere
4. TELOPHASE
Nuclear membrane re-forms

Meiosis



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TM 2.2

Meiosis II

Prophase II | Metaphase II | Anaphase II | Telophase II

Lesson 2: Cell Reproduction and Genetics Name _____

Mitosis and Meiosis

Objective: Simulate the stages of mitosis and meiosis.

Materials and Equipment:

Pipe cleaners
Beads
Pieces of yarn

Procedure:

1. Using pipe cleaners, beads, and pieces of yarn, illustrate the four stages of mitosis. The pipe cleaners and beads should represent the chromosomes. The pieces of yarn can illustrate the nucleus, centrioles, and spindle fibers. Be ready to explain what happens in each of these four stages.

2. Use the pipe cleaners, beads, and yarn to illustrate the four stages of meiosis I. Be sure to show the differences that distinguish meiosis I from mitosis. Be ready to explain each stage of meiosis I.

3. Use the pipe cleaners, beads, and yarn to illustrate the four stages of meiosis II. Be sure to illustrate the crossing over of genes. Be ready to explain each stage of meiosis II.

Key Questions:

1. What are four differences that exist between mitosis and meiosis?

   a.

   b.

   c.

   d.

2. How does meiosis I differ from meiosis II in terms of the genetic material passed on to the new cells?

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 3: Genetic Modification

Objective/Competence: Describe the processes of genetic modification.

Study Questions

1. **What are gene mapping and gene sequencing?**
2. **How is DNA extracted?**
3. **What is restriction digestion?**
4. **What is gel electrophoresis?**
5. **What is gene splicing, and how is it accomplished?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit IV.
2. Transparency Master
   a) TM 3.1: Gel Electrophoresis
3. Activity Sheet
   a) AS 3.1: DNA Extraction

UNIT IV - FOUNDATIONS OF GENETIC ENGINEERING

Lesson 3: Genetic Modification

TEACHING PROCEDURES

A. Review

Lesson 2 discussed how cells reproduce and pass on genetic information. A spontaneous change in the genetic code of a cell or organism is called a mutation. Recombinant DNA technology provides researchers with the tools necessary to intentionally alter specific parts of the genetic code of a cell. This lesson will describe some of these tools.

B. Motivation

Gel electrophoresis can be dramatized by the use of an obstacle course. Configure student chairs or desks to form three obstacle courses. Divide the students into three groups, with two to four students in the first group, four to eight in the second group, and eight to twelve in the third group. All groups should start the obstacle course at the same time and should be instructed not to touch any chair or desk. When the winning team reaches the finish line, all teams must freeze. Explain that the obstacle course represents the agarose gel through which the DNA fragments must pass in gel electrophoresis. The longer the fragment, the slower it will move across the gel.

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students to describe gene mapping and gene sequencing.

What are gene mapping and gene sequencing?

a) Gene mapping is the process of finding the location of genes for specific traits on the chromosomes of an organism. Researchers use gene mapping to select specific genes for modification.
b) Gene sequencing is a process that shows the order of all the base units (A, T, C, G) as they line up on a particular gene. It allows scientists to recognize how to cut out a particular gene or gene fragment.

2. Ask students if DNA is a chemical substance. Because it is a chemical substance, it can be extracted chemically. Use AS 3.1 to allow students to perform a DNA extraction.

How is DNA extracted?

a) The cell membrane or cell wall must be broken down to release the cytoplasm, and the nuclear membrane must also be broken to release the chromosomes.
    1) This can be accomplished with a surfactant, which is a fatty acid compound like detergent.
    2) Heat accelerates this process.
b) Next, a protease must be used to split the protein contents of the cell, including protein molecules called histones, around which the DNA strands are wrapped.
c) The last step involves separating the DNA from the other cell components. Cold alcohol is added to the cellular solution; the DNA clumps together and rises to the top of the alcohol.

3. Ask students what scissors are used for. Discuss how restriction digestion works.

What is restriction digestion?

a) Restriction digestion is the process of cutting DNA into smaller fragments with restriction enzymes.
b) Restriction enzymes are essentially biochemical scissors; each restriction enzyme cuts DNA at a different sequence of base pairs.
c) Researchers use restriction enzymes to cut genes or DNA fragments out of extracted DNA strands.

4. Ask students to recall the lesson in which DNA fingerprinting was discussed. Explain that the bands that make up the DNA fingerprint are a result of gel electrophoresis. Discuss the process of gel electrophoresis. Use TM 3.1 to illustrate how gel electrophoresis works.

What is gel electrophoresis?

a) Gel electrophoresis is a process in which an electric current is applied to a gel to separate different lengths of DNA fragments into groups; researchers can then recover a desired gene or gene fragment.
b) It requires an electrophoresis box, a buffer solution, a special power supply, and a gel made from agarose or another agent.
c) One end of the electrophoresis box has a positive pole and the other a negative pole.
d) DNA fragments to which a dye has been added are placed in small wells or pockets at the end of gel nearest the negative pole, and an electric current is applied to the gel.
e) Since DNA fragments are negatively charged, they will be repelled away from the negative pole and attracted to the positive pole.
f) Short lengths of DNA will move through the gel faster than long lengths.
g) When the electric current is removed, the fragments of DNA of the same size will be grouped at a one spot on the gel, which is called a band.

5. Ask students to define the term splicing. Explain that gene splicing is like splicing two pieces of rope together using a third piece of rope.

What is gene-splicing, and how is it accomplished?

a) Gene-splicing is the process of inserting a piece of DNA into a chromosome of a cell.
b) Gene-splicing is also called ligation because the enzyme ligase is the biochemical glue that joins the pieces of DNA.
c) Gene-splicing requires several steps.
    1) The researcher cuts out a piece of DNA with a restriction enzyme; the correct enzyme must be used so that the DNA contains complementary bases.
    2) Gel electrophoresis must be performed to separate the DNA fragments by size and isolate the appropriate fragment.
    3) The researcher joins the ends of the selected fragment to the DNA being transformed through a chemical reaction called a ligase reaction.
    4) The result is a cell containing DNA from two different sources, which is therefore called recombinant DNA.

F. Other Activities

1. Use pop beads to show how restriction digestion works.

2. If possible, use restriction analysis and gel electrophoresis experiments such as those found in the curriculum guide *An Introduction to Biotechnology: A Unit for High School Students (Book Three)* published by Kendall/Hunt.

G. Conclusion

This lesson describes some of the most common techniques used by molecular biologists involved in biotechnology research. A knowledge of these techniques will provide a basic understanding of exactly how DNA is manipulated.

H. Answers to Activity Sheet

AS 4.1

1. The soap helped break down the cell membranes and release the chromosomes.

2. Heating the solution accelerated the breakdown of the membranes. Most of the lipids and proteins precipitated out of the solution. However, the solution needed to be cooled after heating to avoid the soap breaking down the DNA.

3. The meat tenderizer contains the enzyme papain, which breaks down proteins.

4. DNA is the only component of the cell that is not soluble in alcohol and therefore precipitates out.

5. (Students should speculate on this question but may not be able to come up with this answer.) The DNA was not pure because some of the other cellular components could have clung to the DNA. It must be washed in alcohol several times to be pure.

I. Answers to the Evaluation

1. d
2. b
3. a
4. c
5. d

6. a) The cell membrane or cell wall and nuclear membranes are broken down with the use of a surfactant.
   b) Protease is used to break down the protein contents of the cell, including histones, around which the DNA is wrapped.
   c) DNA is separated from the other cell components by adding cold alcohol to the cellular solution, which causes the DNA to clump together and rise to the top of the alcohol.

7. Gene sequencing is a process that shows the order of all the base units (A, T, C, G) as they line up on a particular gene.

8. Restriction digestion is the process of cutting DNA into smaller fragments with restriction enzymes.

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is considered to be a type of biochemical scissors?

   a. Agarose gel
   b. Histones
   c. Ligase
   d. Restriction enzymes

2. When a researcher does gel electrophoresis, what causes the DNA fragments to move across the gel?

   a. Buffer solution flows across the gel, moving the DNA fragments.
   b. Negatively charged DNA is repelled away from the negative pole and attracted toward the positive pole of the electrophoresis box.
   c. Positively charged DNA is repelled away from the positive pole and attracted toward the negative pole of the electrophoresis box.
   d. A chemical reaction involving ligase causes the movement of the DNA.

3. Ligase is an enzyme that:

   a. Chemically joins two DNA fragments.
   b. Acts as a restriction enzyme.
   c. Is used in the gel electrophoresis buffer solution.
   d. Is used in DNA extractions to break down the lipid components of the cell.

4. Surfactants, which are similar to detergents:

   a. Break down the protein contents of the cell.
   b. Cause DNA to float to the top of a cellular solution.
   c. Break down the cellular membranes.
   d. Speed up the process of DNA extraction.

5. Gene mapping can be defined as the:

   a. Process that allows researchers to separate different lengths of DNA fragments into groups.
   b. Process of inserting a piece of DNA into a chromosome of a cell.
   c. Process that finds the order of all the base units as they line up on a particular gene.
   d. Process of finding the location of genes on the chromosomes of an organism.

Complete the following short answer questions.

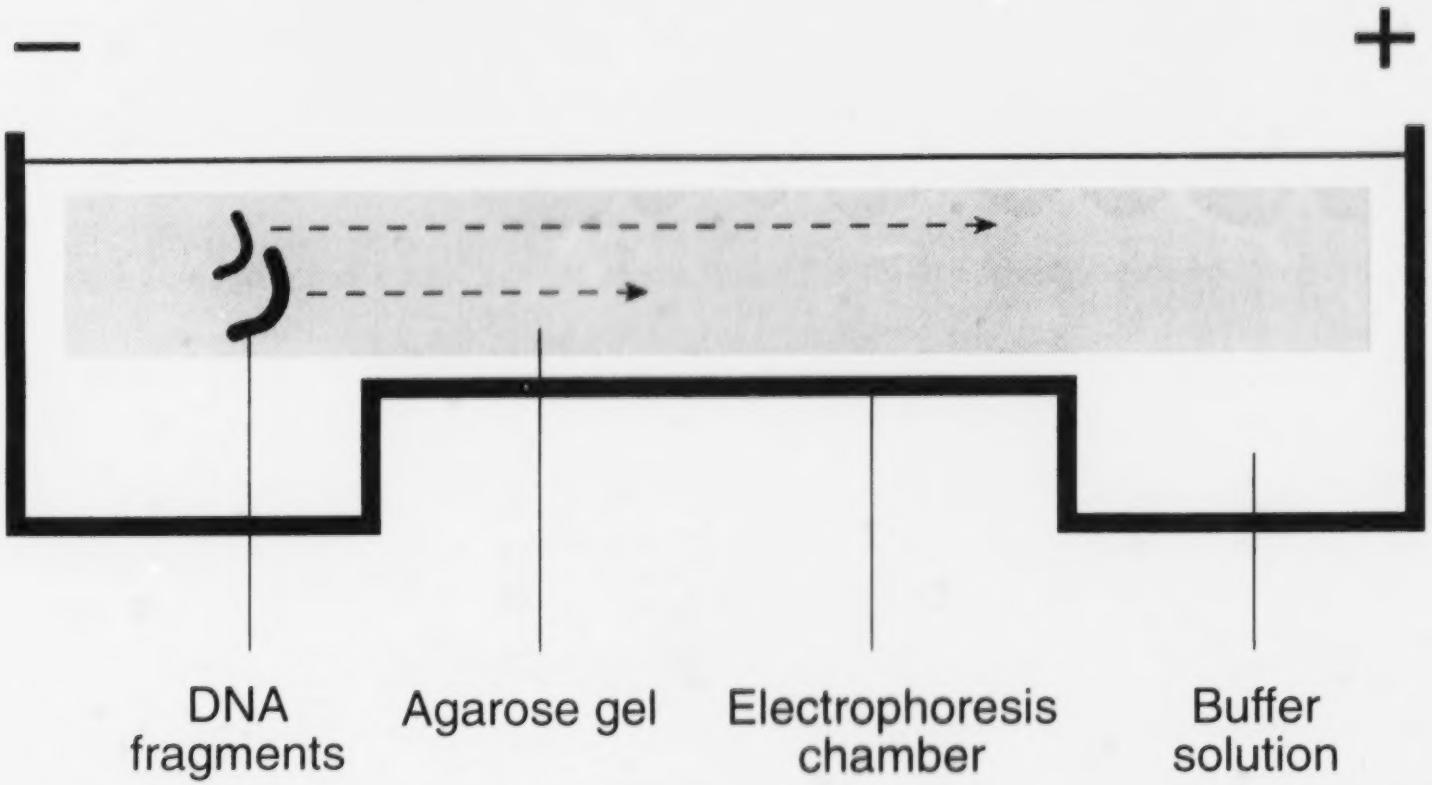
6. What are the three major steps of the DNA extraction process?

   a.

   b.

   c.

Gel Electrophoresis



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TM 3.1

Lesson 3: Genetic Modification Name _____

DNA Extraction

Objective: Perform DNA extraction.

Materials and Equipment:

1 hot water bath or hot plate set at 55 to 60 degrees Celcius
1 candy or laboratory thermometer (to regulate the hot water bath)
1 cold water bath (ice water in a large bowl)

Materials needed for each group of students:

1 glass or plastic graduated cylinder (100 ml)
1 plastic teaspoon
1 Pyrex glass or heat-resistant plastic beaker or flask (500 ml or larger)
1 piece of glass tubing bent to a 90 degree angle at the end
1 funnel or strainer with a coffee filter
2 flat toothpicks
1 medicine dropper or pipette
1 container of liquid soap (Woolite, laundry soap, or dish soap)
1 test tube for each student
½ medium onion, chopped (should not be finely chopped)
Refrigerated alcohol
Meat tenderizer

Procedure:

1. Observe the instructor as he or she performs steps 2-6.

2. Measure out 5 ml of soap and leave it in the graduated cylinder. Add ¼ teaspoon of salt to the soap. Next, add water to the soap until a total volume of 50 ml is reached. Set the cylinder aside. Place the onion in the beaker or flask. Pour the soap and salt water solution over the chopped onion.

3. Put the beaker or flask containing the onion solution into the hot water bath or onto the hot plate. Check to make sure that the temperature is approximately 55 to 60 degrees Celcius. The onion solution should be heated for 10 to 12 minutes. If the solution is heated for more than 15 minutes, the DNA will break down. Slowly stir the mixture periodically but not so much as to create foam. Make sure to record the time you placed the beaker or flask in the heating environment.

4. After 10 to 12 minutes, remove the solution from the hot water bath or hot plate and place it in the ice water bath for five minutes. Stir the solution slowly while it is cooling.

5. Filter the solution into a plastic cup using the funnel or strainer and coffee filter. Try to avoid getting any foam into the filtered mixture. This filtering procedure may be a slow process; if needed, it can be left to filter overnight in a refrigerator.

6. Divide the filtered solution into the test tubes, placing about one teaspoon in each. Stir the filtered solution while dividing it. The test tubes can be stored in the refrigerator overnight.

7. Add two toothpicks full of meat tenderizer to the solution in the test tubes and **gently** mix. Next, add **cold** alcohol to the solution until a 1 cm layer of alcohol forms on top of the solution. This can be done by using

a medicine dropper or pipette. **Do not mix the solution!** Watch as the DNA begins to precipitate out into the alcohol. The bent piece of glass tubing can be used to spool the DNA. The DNA will look like white mucus.

Key Questions:

1. What did the soap do to aid in the extraction of the DNA?

2. Why was the onion solution heated and then cooled?

3. Why was meat tenderizer used? (Hint: Look at the ingredients in the meat tenderizer.)

4. Why did the DNA precipitate out in the alcohol?

5. Do you think the DNA obtained was pure? Why or why not?

UNIT V - ANIMAL TECHNOLOGIES

Lesson 1: Artificial Insemination

Objective/Competency: Describe the process of artificial insemination.

Study Questions

1. **What is artificial insemination?**
2. **What are the benefits of artificial insemination compared to natural breeding?**
3. **What equipment is needed for artificial insemination?**
4. **What steps are involved in artificial insemination?**
5. **How can the estrous cycle be manipulated to aid in artificial insemination?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.

2. Activity Sheet

   a) AS 1.1: Evaluating Semen

UNIT V - ANIMAL TECHNOLOGIES

Lesson 1: Artificial Insemination

TEACHING PROCEDURES

A. Introduction

Biotechnology has been used in the animal industry for many years. Animal biotechnology has its foundation in selective breeding practices. In the early twentieth century, animal biotechnology included artificial insemination. In the late 1970s, embryo transfer technology emerged in the animal industry. In 1997 animal cloning was performed using an adult sheep, and biotechnology continues to open new opportunities in animal production. This lesson will examine the technology of artificial insemination.

B. Motivation

The livestock industry is becoming an industry that demands a more uniform product. How does a producer achieve this improved level of product quality? Many producers are using artificial insemination to accomplish this goal. Purebred producers who want exceptional breeding stock but view buying superior male animals as too expensive commonly use artificial insemination. Artificial insemination technology has also made the international exchange of breeding stock economically feasible.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to define artificial insemination in their own words.

What is artificial insemination?

Artificial insemination is the process of collecting semen from a male animal and placing it in the reproductive tract of a female animal.

2. Ask students what the benefits of artificial insemination are.

What are the benefits of artificial insemination compared to natural breeding?

a) AI allows for the selection and use of male animals regardless of where the animals are physically located.
b) AI helps reduce the spread of reproductive or venereal diseases.
c) AI reduces or eliminates the cost of owning and maintaining a male animal.
d) The genetic improvement of livestock through the use of superior animals occurs more quickly due to a dramatic increase in the number of offspring a male animal can produce (sire) per year.

3. Show students the actual equipment used in AI or pictures of the equipment.

What equipment is needed for artificial insemination?

a) Dummy - female replica mounted by male so that semen can be collected
b) Artificial vagina - water-filled plastic sheath used to collect the semen
c) Microscope - to check the quality of the semen

d) Semen straw - thin plastic tube used to store the amount of semen needed to inseminate one female
e) Semen tank - aluminum tank used to store semen in liquid nitrogen
f) Insemination instrument - syringe-like tool that holds the straw and deposits the semen into the reproductive tract

4. Ask students to describe the process of artificial insemination. Have students complete AS 1.1. Students must be given pictures of primary, secondary, and tertiary sperm abnormalities to complete the activity. These pictures may be available in reproductive physiology or veterinary husbandry textbooks. Point out that the activity only addresses a few factors that affect the quality of sperm and does not provide an absolute measure of fertility.

What steps are involved in artificial insemination?

a) Semen is collected using an artificial vagina.
b) The semen is tested for quality, which is determined by the motility, shape, and quantity of the sperm.
c) Extenders are added to increase the volume. The extenders that are most commonly used are citrate, egg-yolk phosphate, and homogenized milk.
d) The semen is placed in straws and frozen in liquid nitrogen at -320 degrees Fahrenheit.
e) The timing of insemination must be carefully managed; generally, insemination should occur shortly before ovulation.
f) The semen must be properly thawed.
g) A trained technician should inseminate the female by placing the straw in the inseminating instrument, which is inserted into the vagina and guided through the cervix; the semen is placed at the end of the cervix or the beginning of the uterus.

5. Ask students why one would want to manipulate the estrous cycle of animals. Explain that if producers can breed all of the animals at once management costs will be reduced and the resulting offspring will be more uniform in age.

How can the estrous cycle be manipulated to aid in artificial insemination?

a) Through the injection of certain hormones that affect the estrous cycle, a producer can cause females to begin estrous as a group.
b) This process, which is called estrous synchronization, simplifies the management of an artificial insemination program because animals in the group can all be bred within one or two days of each other.

F. Other Activities

1. Obtain a cow's reproductive tract from a slaughterhouse and demonstrate the insemination process.

2. Invite a local AI technician to bring AI equipment and talk to the class.

3. Arrange a field trip to observe a technician performing AI.

G. Conclusion

Artificial insemination is an important management practice for livestock producers. The availability of a wide selection of animals for breeding and accurate performance records motivate producers to use artificial insemination. The dairy industry most commonly uses AI. However, beef cattle producers, dog breeders, horse breeders, and swine producers are using AI more frequently.

H. Answers to the Activity Sheet

AS 1.1

Answers will vary.

I. Answers to the Evaluation

1. b
2. d

3. Based on the motility, shape, and quantity of the sperm

4. Students may list any three of the following: dummy, artificial vagina, microscope, semen straws, semen tank, or insemination instrument.

5. Students may list any of two of the following.

   - AI allows for the selection and use of male animals regardless of where the animals are physically located.
   - AI helps reduce the spread of reproductive and venereal diseases.
   - AI reduces or eliminates the cost of owning and maintaining a male animal.
   - The genetic improvement of livestock through the use of superior animals occurs more quickly due to a dramatic increase in the number of offspring a male animal can have per year.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 1: Artificial Insemination Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Artificial insemination (AI) can be defined as the:

   a. Process of depositing sperm.
   b. Process of collecting sperm from a male animal and placing it in the female reproductive tract.
   c. Process of collecting an egg from a female animal, fertilizing it, and placing it in the reproductive tract of another female animal.
   d. Process of fusing a sperm and an egg.

2. How is the estrous cycle manipulated?

   a. Through the injection of vitamins
   b. By using artificial insemination
   c. By placing a group of females together
   d. Through the injection of hormones

Complete the following short answer questions.

3. How is the quality of semen evaluated?

4. What are three pieces of equipment used in artificial insemination?

   a.

   b.

   c.

5. What are two benefits of artificial insemination?

   a.

   b.

Lesson 1: Artificial Insemination Name _____

Evaluating Semen

Objective: Visually examine semen to evaluate semen quality.

Materials and Equipment:

Microscope with a 100x oil immersion objective
Small amount of immersion oil
Hot water bath (at approximately 98°F)
Several glass test tubes
Microscope slides and cover slips
Frozen semen samples
Semen stain (Blom's Esin-Nigrosin stain)
Several eye droppers

Procedure:

1. Place the semen sample in test tubes in the water bath.

2. Place the microscope slides and cover slips in the water bath; they should be warm when used.

Evaluation of Individual Motility

3. Place one drop of semen on a slide and place a cover slip over it. Using a 40x objective, focus the microscope and observe the sample. Select an individual sperm cell and observe the speed at which it moves. Observe ten different sperm cells and use the chart below to find the score for each of these sperm cells based on how long it takes for each of them to move across the viewing field. Total the scores and divide by ten to calculate the individual motility score for the semen sample.

Observed Behavior	Points
Very rapid forward motion that may be hard to follow	5
Rapid forward progression	4
Steady forward progression at a moderate speed	3
Slow progression or slightly erratic (stop and start) motion	2
Weak rocking movement without forward motion	1
No motion	0

Average score _____

Evaluation of Sperm Morphology (Sperm Structure)

4. Place one drop of semen on a slide and add one drop of semen stain. Mix the semen and stain together and place the cover slip on the solution.

5. Using oil immersion, focus the microscope. Next, search for an area that has at least five sperm cells in the viewing field. Count and record the number of sperm in the field. Use the pictures of sperm abnormalities provided by your instructor to help you identify abnormal sperm cells. Count and record the number of abnormal cells that have primary abnormalities (those relating to the sperm head and the caplike structure at its tip) and the number with secondary (involving droplets on the tail) or tertiary (other

defects of the tail) abnormalities. Select a new group of sperm cells and repeat this process until 100 cells have been observed.

6. Score the morphology of the semen sample.

Primary Abnormalities	Points
less than 10	20
10 to 19	15
20 to 29	10
more than 29	5

Secondary and Tertiary Abnormalities	Points
less than 25	20
26 to 39	15
40 to 59	10
more than 59	5

7. Calculate the average morphology by finding the sum of the primary abnormalities and the secondary and tertiary abnormalities and dividing by two.

Primary abnormalities score _____

Secondary and tertiary abnormalities score _____

Total _____ ÷ 2

Average score _____

UNIT V - ANIMAL TECHNOLOGIES

Lesson 2: Embryo Transfer Technologies

Objective/Competency: Describe the process of embryo transfer.

Study Questions

1. **What is embryo transfer?**
2. **What are the advantages of embryo transfer?**
3. **What equipment is needed for embryo transfer?**
4. **How is the donor managed for superovulation?**
5. **What are the steps in the embryo flush process?**
6. **What are the steps in transferring the embryo to the recipient?**
7. **What is cloning, and how is it accomplished?**
8. **What are the benefits of cloning?**
9. **What is in vitro fertilization (IVF)?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.
2. Transparency Master
   a) TM 2.1: Catheter
3. Activity Sheets
   a) AS 2.1: Examining Embryos (Instructor)
   b) AS 2.1: Examining Embryos (Student)

UNIT V - ANIMAL TECHNOLOGIES

Lesson 2: Embryo Transfer Technologies

TEACHING PROCEDURES

A. Review

As discussed in Lesson 1, the use of artificial insemination in the livestock industry has enabled livestock producers to select highly desirable male animals for their breeding programs. However, producers must own many high quality female animals to improve a herd's genetic potential rapidly. Through the development of embryo transfer technologies, producers can obtain high quality embryos and improve the genetic potential of their herds more quickly.

B. Motivation

Congratulations! Your two-year-old heifer has been named Grand Champion at four major Angus shows across the country. You have put a great deal of hard work and money into this animal, and now you have the opportunity to make money by raising or selling calves. You could use embryo transfer. If semen from a prizewinning bull is used in the embryo transfer process and three or four live births are predicted, would you choose to use embryo transfer technology? What are the factors that might influence your decision?

C. Assignment

D. Supervised Study

E. Discussion

1. Remind students that an embryo is a fertilized egg. Ask them to explain what embryo transfer is.

   What is embryo transfer?

   a) Embryo transfer (ET) is the process of transplanting embryos from a donor female to a recipient female.
   b) Embryo transfer has six basic steps.
      1) Synchronization of estrous in donor and recipient
      2) Superovulation of the donor
      3) Breeding the donor
      4) Recovering the embryos from the donor through flushing
      5) Isolating and examining the embryos
      6) Transferring embryos to the recipients or freezing the embryos

2. Ask students to identify when embryo transfer might be of the greatest benefit.

   What are the advantages of embryo transfer?

   a) Increases the reproductive potential of superior females
   b) Increases the rate of genetic improvement in a herd
   c) Allows female animals to be progeny tested more easily and accurately
   d) Provides a way to use breeding stock from other countries

3. Point out to students that some of the equipment used in embryo transfer is similar to the equipment used in AI. Show students a semen straw and an embryo straw as examples. Discuss the equipment used in ET.

What equipment is needed for embryo transfer?

a) Equipment needed to flush a donor
   1) Catheter
   2) Stylet
   3) Collection cylinder
   4) Shoulder-length glove
   5) Lubricant
   6) Syringes
b) Equipment needed to examine the embryos
   1) Microscope
   2) Pipette embryo-handling tool
   3) Gridded search dish
c) Equipment needed to transfer the embryo to a recipient
   1) Embryo straw
   2) Embryo transfer gun

4. Ask students to recall the name of the hormone that causes the follicle (egg or ovum) to be released at ovulation. Tell students that if large amounts of this hormone (FSH) are given, multiple eggs will be released.

How is the donor managed for superovulation?

a) If prostaglandin is used to manipulate the heat cycle, preparation of the donor cow begins ten days after she is in standing heat with an injection of the hormone FSH.
b) FSH injections are given once in the morning and once in the evening until a total of seven injections have been given.
c) Prostaglandin is injected in the morning and evening on the third day of the procedure, which causes the donor to come into estrus in 48 hours.
d) When estrus begins, the donor is bred naturally or through AI.

5. Ask students where the egg cells (ova) are produced. Explain that each female animal has thousands of immature ova in their ovaries. Review the reproductive cycle of the female, focusing on ovulation. Have students complete AS 2.1.

What are the steps in the embryo flush process?

a) The embryo flush process is performed seven days after breeding.
b) An epidural anesthesia is injected into the space between two cervical vertebrae.
c) With the aid of the stylet, the catheter is inserted into the vagina, through the cervix, and into the right uterine horn.
d) The technician must palpate the donor carefully to guide the catheter into the right location.
e) The inflatable bulb near the end of the catheter is inflated to block off the uterine horn while it is being flushed.
f) The sterile flushing solution is allowed to flow into the uterine horn under the force of gravity until 500 milliliters of the solution is in the uterine horn, and the horn is then massaged to loosen the embryos.
g) When the fluid has filled the uterine horn, the outlet tube of the catheter is opened and the fluid and embryos are collected in a collection cylinder.
h) This process is repeated in the left uterine horn.
i) The embryos settle to the bottom of the collected fluid, and the fluid is siphoned off so the embryos can be counted and characterized, or examined for quality.

6. Describe the procedure for transplanting the collected embryo into the recipient.

What are the steps in transferring the embryo to the recipient?

a) Embryos that are to be transferred to recipients are loaded into plastic embryo straws.
b) They are then prepared to be either transferred into recipient cows or frozen in a container of liquid nitrogen at -320 degrees Fahrenheit.
c) The embryo transfer gun is loaded with a straw and inserted into the vagina.
d) It is guided through the cervix and into the uterus, where the embryo is expelled.

7. Ask students to give examples of animals that have been cloned. Explain that sheep, cattle, and goats have all been cloned.

What is cloning, and how is it accomplished?

a) Cloning - the asexual reproduction of an organism in which the resulting organisms are identical
b) Two methods of cloning
    1) Splitting an embryo
        (a) A researcher physically splits the embryo into two halves as it is dividing.
        (b) Each half is transferred to a recipient and develops normally.
    2) Nuclear transfer
        (a) A cell is extracted from a parent organism, and an electrical pulse is used to fuse it to an unfertilized ovum that has had its nucleus removed.
        (b) The new cell has a diploid number of chromosomes and will develop as if it were a natural embryo; however, it must be stimulated to act like a fertilized ovum and begin dividing.

8. Ask students to list some reasons why a group of genetically identical animals could be useful.

What are the benefits of cloning?

a) Cloning can increase the number of highly prized animals produced.
b) Fewer animals could be used in live animal tests because all of the animals--control animals and experimental animals--would be identical.
c) Animals genetically altered to produce pharmaceuticals could be cloned, which would reduce the cost of producing the animals.

9. Ask students to recall what in vitro means ("in glass"). Explain that IVF is one of the newest biotechnologies. A few dairy producers have begun to use it.

What is in vitro fertilization (IVF)?

a) IVF is a process in which immature follicles are collected from the ovaries of a female animal, stimulated to mature, and fertilized outside the female reproductive tract.
b) The fertilized embryos can be transferred to recipient animals.

F. Other Activities

1. Using a female reproductive tract from a slaughterhouse, simulate the embryo transfer process.

2. Show the video "Embryo Transfer" from Creative Educational Video (CEV), which is available from MVRC.

3. Contact an ET technician or veterinarian and ask if he or she would bring the ET equipment to class or if the class could borrow the equipment for a day so students could do an equipment identification activity.

4. Take students to a farm or veterinarian's office to observe an actual or simulated nonsurgical flush.

G. Conclusion

In the early 1980s, embryo transfer was an expensive and difficult process involving the surgical removal of embryos. Today, more and more producers, particularly those who produce breeding animals, are looking to embryo transfer to give them more progeny from their high performing animals.

H. Answers to Activity Sheet

AS 2.1

Answers will vary.

I. Answers to the Evaluation

1. d
2. b
3. d
4. c
5. b
6. d
7. 3
8. 2
9. 4
10. 1

11. Students may list any two of the following.
    - Cloning can increase the number of highly prized animals produced.
    - Fewer animals could be used in live animal tests because all of the animals--control animals and experimental animals--would be identical.
    - Animals genetically altered to produce pharmaceuticals could be cloned, which would reduce the cost of producing the animals.

12. Embryo transfer (ET) is the process of transplanting embryos from a donor female to a recipient female.

13. IVF is a process in which immature follicles are collected from the ovaries of a female animal, stimulated to mature, and fertilized outside the female reproductive tract. The fertilized embryos can be transferred to recipient animals.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 2: Embryo Transfer Technologies Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is <u>not</u> an advantage of embryo transfer technology?

   a. Embryo transfer allows for easier and more accurate progeny testing of female animals.
   b. Embryo transfer provides a way to use breeding stock from other countries.
   c. Embryo transfer increases the rate of genetic improvement in a herd.
   d. Embryo transfer reduces the management needed for breeding programs.

2. A stylet is used to:

   a. Insert the embryo into the recipient.
   b. Insert the catheter into the donor for the flushing procedure.
   c. Manipulate the embryos when counting and grading them.
   d. Collect the embryos after they have been flushed.

3. The hormone that causes a cow to superovulate is:

   a. Prostaglandin.
   b. Syncromate-B.
   c. Progesterone.
   d. Follicle stimulating hormone.

4. How many days after a donor cow has been superovulated and bred is the flush procedure done?

   a. 2
   b. 3
   c. 7
   d. 11

5. The process in which a cell is extracted from a parent organism and fused into an ovum that has had its nucleus removed is called:

   a. In vitro fertilization.
   b. Nuclear transfer.
   c. Embryo splitting.
   d. Embryo flushing.

6. Which of the following is <u>not</u> equipment required for embryo transfer?

   a. Catheter
   b. Straw
   c. Collection cylinder
   d. Surgical supplies

Superovulation involves several steps. Put the following steps in the correct order by placing "1" by the first step, "2" by the second step, etc.

7. _____ Prostaglandin is injected into the donor cow.

8. _____ The donor cow is injected with FSH.

9. _____ The donor cow is bred.

10. _____ Ten days pass after estrous is detected in the donor cow.

Complete the following short answer questions.

11. What are two reasons cloning may be useful?

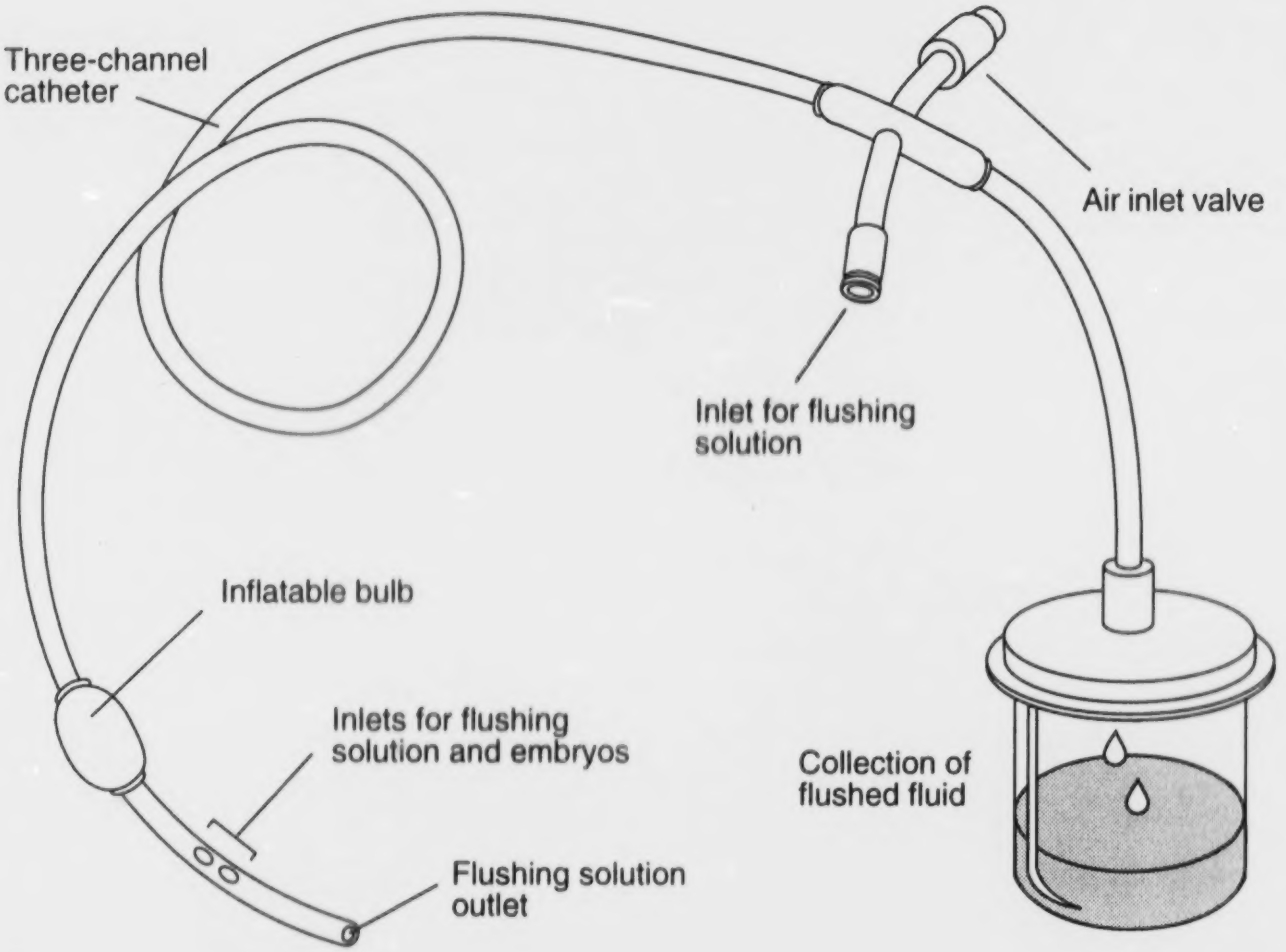
    a.

    b.

12. What is embryo transfer?

13. What is in vitro fertilization?

Catheter



TM 2.1

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Lesson 2: Embryo Transfer Technologies

Examining Embryos

Objective: Examine and grade embryos.

Materials and Equipment:

1-5 microscopes (magnifying **less** than 100x, preferably 10x and 50x)
4-6 petri dishes (preferably gridded dishes)
500 ml of embryo-holding media or flushing fluid
Liquid nitrogen tank
Warm water bath

Procedure:

Before conducting this activity, frozen cattle embryos must be obtained from a local breeding service or veterinarian. Embryos can also be obtained from ABS (American Breeders Service) for a fee; the price charged for these embryos will vary.

Obtain a tank containing liquid nitrogen from a local veterinarian or livestock breeder to store the embryos correctly. Remember to thaw the embryos properly by first allowing them to warm in the air for 10 to 15 seconds and then placing them in a warm water bath. Place a known number of embryos in a gridded petri dish containing holding solution and label it "A." Place a single Grade 1, Grade 2, or Grade 3 embryo in each of the other petri dishes and label them "B," "C," and "D"; these dishes should contain holding media and have a lid.

Note: It can sometimes be difficult to find Grade 3 embryos, since they are not often frozen.

Divide students into groups. The number of groups will depend on the number of microscope observation stations. Place one or more of the petri dishes containing embryos at each station. Demonstrate how to remove the cover and focus the microscope so that the embryos in the dish are visible. Have the students examine the embryos and complete the activity.

Lesson 2: Embryo Transfer Technologies Name_____

Examining Embryos

Objective: Examine and grade embryos.

Materials and Equipment:

1-5 microscopes (magnifying **less** than 100x, preferably 10x and 50x)
4-6 petri dishes (preferably gridded dishes)
500 ml of embryo-holding media or flushing fluid
Liquid nitrogen tank
Warm water bath

Procedure:

1. Use the microscope to observe each of the petri dishes prepared by your instructor.

2. Count the embryos in dish "A" and record the number in the space provided. _____

3. Grade the embryos in dishes "B," "C," and "D." The different classifications used when grading embryos are described below.

   Grade 1: The embryo is nearly perfect. More than 98 percent of the cells in the embryo are apparently active. It is rounded in appearance.

   Grade 2: The cell mass of the embryo is apparently 70 to 98 percent active. Some cells are extruded from the surface of the embryo, so it may not be rounded in appearance.

   Grade 3: Less than 70 percent of the cell mass of these embryos is apparently active. Several cells are extruded from the surface of the embryo, which may be severely malformed.

   Degenerate: None of the cell mass of the embryo appears active. It may be flat or concave in shape.

4. Answer the following questions.

   a. What is the grade of the embryo in dish "B"?

   b. What is the grade of the embryo in dish "C"?

   c. What is the grade of the embryo in dish "D"?

UNIT V - ANIMAL TECHNOLOGIES

Lesson 3: Applications of Biotechnology in Animal Agriculture

Objective/Competency: Identify other applications of biotechnology in animals.

Study Questions

1. **What are supplemental hormones?**
2. **How is biotechnology used to produce supplemental hormones and animal health products?**
3. **How is DNA fingerprinting used in the livestock industry?**
4. **What are the emerging applications of biotechnology in the animal industry?**

References

1. *Biotechnology: Application in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.
2. Transparency Master
   a) TM 3.1: Producing BST
3. Activity Sheet
   a) AS 3.1: Emerging Applications of Biotechnology

Lesson 3: Applications of Biotechnology in Animal Agriculture

TEACHING PROCEDURES

A. Review

Livestock producers have benefited from advances in biotechnology like artificial insemination and embryo transfer. Biotechnology is now having an impact on livestock performance in ways not directly related to breeding. The development of economical growth hormones, genetically engineered vaccines, and other products has begun to affect animal agriculture substantially.

B. Motivation

A swine producer annually markets approximately 800 hogs weighing an average of 220 pounds each and receives an average price of $0.49 per pound for them. If the producer could increase production by 12 percent by using a biotechnology product, how much is the product worth to the producer? Assume that the biotechnology product costs $3.50 per pig. The animals would produce 21,120 additional pounds of pork, worth $10,348.80. Subtracting $2,800 for buying the product leaves the producer with $7,548.80 in extra income. A hormone supplement that can increase pork production is nearing the marketing stage.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to recall what hormones are. Explain that hormones are complex proteins that trigger certain chemical changes in an animal's body. Discuss the use of supplemental hormones.

   What are supplemental hormones?

   a) Supplemental hormones are chemical messengers administered to animals to stimulate them to grow, produce more milk, or improve their performance in another way.
   b) Bovine somatotropin (BST) - When injected into a cow, BST causes a secondary hormone to be released that increases blood flow in the mammary glands, thus increasing the amount of milk produced.
   c) Porcine somatotropin (PST) - When injected into a pig, the hormone causes the pig to grow about 15 percent faster and consume 20 percent less feed; muscle mass increases, while backfat is reduced.
   d) Growth hormone releasing factor (GHRF) - GHRF is not itself a hormone, but it stimulates the pituitary gland to release larger amounts of growth hormones.
   e) Chicken growth hormone and chicken molting hormone - The growth hormone shortens the time needed for broilers to reach market size by 15 percent, while the molting hormone increases egg production.

2. Use TM 3.1 to show the process of producing BST by genetically modifying bacteria. Discuss other applications of biotechnology in producing animal health products.

How is biotechnology used to produce supplemental hormones and animal health products?

a) Supplemental hormones
   1) The gene responsible for the production of somatotropin was inserted into a plasmid taken from a bacterium; the plasmid ring was opened with a restriction enzyme, and the gene was spliced into the opening.
   2) The plasmid was reinserted into the bacterium.
   3) Modified bacteria are placed in a fermentation tank under ideal conditions for growth and division.
   4) After a substantial number of bacteria are produced, the somatotropin can be purified from the bacteria.

b) Animal health products
   1) Monoclonal antibody technology - Monoclonal antibodies are produced by fusing together a tumor cell and an immune system cell that produces antibodies against a specific antigen, yielding a cell that divides rapidly and produces the desired antibody.
   2) Therapeutic proteins
      (a) When injected, therapeutic proteins like interferon and interleukin-2 attack viruses; they also stimulate the animal's immune system to attack the viruses.
      (b) They are produced by genetically modified bacteria.
   3) Genetically engineered vaccines - These vaccines produced by genetically modified bacteria contain only the antigen of the disease-causing organism, which triggers the immune system to produce antibodies against the antigen.

3. Ask students to recall what a DNA fingerprint is and how it is made. Ask students how DNA fingerprinting is used in the livestock industry.

How is DNA fingerprinting used in the livestock industry?

DNA fingerprinting is used in the livestock industry to positively identify individual animals, such as stolen animals, offspring for breed registration, and transgenic animals for patent purposes.

4. Ask students to speculate about the possible benefits of cloning adult livestock. Explain that possible applications of a technology play an important part in driving research efforts. Discuss other emerging applications of biotechnology. Have students complete AS 3.1.

What are the emerging applications of biotechnology in the animal industry?

a) New vaccines, such as vaccines for foot rot in cattle and strangles in horses
b) Protein for livestock feeds that are produced by genetically modified bacteria
c) Engineered rumen bacteria that allow animals to better use feedstuffs that are normally hard to digest
d) Cloning of adult animals

F. Other Activities

1. Show the class a simulated DNA fingerprint to have students match an animal to its parents. A mock DNA fingerprint can be created by drawing in lines representing bands for different animals. Refer to Lesson 3 in Unit 2.

2. Have students search the Internet for current biotechnologies being developed that would affect animal agriculture.

G. Conclusion

Research in biotechnology is very expensive, but if the potential income for products is high enough, someone will do the research. The actual application of biotechnology to the livestock industry is very slow. However, biotechnology products are now being used on a daily basis. Livestock producers will use these tools if they prove to be both effective and economical.

H. Answers to the Activity Sheet

AS 3.1

Answers will vary with the sources used.

I. Answers to the Evaluation

1. c
2. b
3. d
4. b
5. a

6. Monoclonal antibodies are produced by fusing together a tumor cell and an immune system cell that produces antibodies against a specific antigen, yielding a cell that divides rapidly and produces the desired antibody.

7. The livestock feed industry is developing genetically modified bacteria that produce protein for feeds and engineered rumen bacteria that allow animals to better use feedstuffs that are hard to digest.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 3: Applications of Biotechnology in Animal Agriculture Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What are supplemental hormones?

   a. Organic substances produced by endocrine glands and carried in the bloodstream to produce a metabolic effect
   b. Genetically modified bacteria that contain the antigen of a disease and trigger the immune system to produce antibodies
   c. Chemical messengers administered to animals to stimulate growth, milk production, or other types of performance
   d. Therapeutic proteins that stimulate an animal's immune system to attack viruses

2. Why is bovine somatotropin (BST) used?

   a. It stimulates the pituitary gland to release larger amounts of growth hormones.
   b. It causes a secondary hormone to be released that increases blood flow in the mammary glands, thus increasing the amount of milk.
   c. It reduces animal fat and increases muscle mass.
   d. It causes the animal to grow about 15 percent faster and consume 20 percent less feed.

3. How are supplemental hormones produced by biotechnology?

   a. By fusing a tumor cell and an immune system cell that produces antibodies against a specific antigen
   b. Drawing the hormone from the endocrine gland with a syringe
   c. Collecting the hormone from the brains of slaughtered animals
   d. Genetically modifying bacteria with the gene responsible for production of the hormone

4. What is <u>not</u> a reason to use DNA fingerprinting in the livestock industry?

   a. To identify individual animals
   b. To prevent the spread of disease
   c. To verify the parentage of an offspring animal
   d. To identify transgenic animals for patenting

5. Which of the following is an example of a currently emerging application of biotechnology in the animal industry?

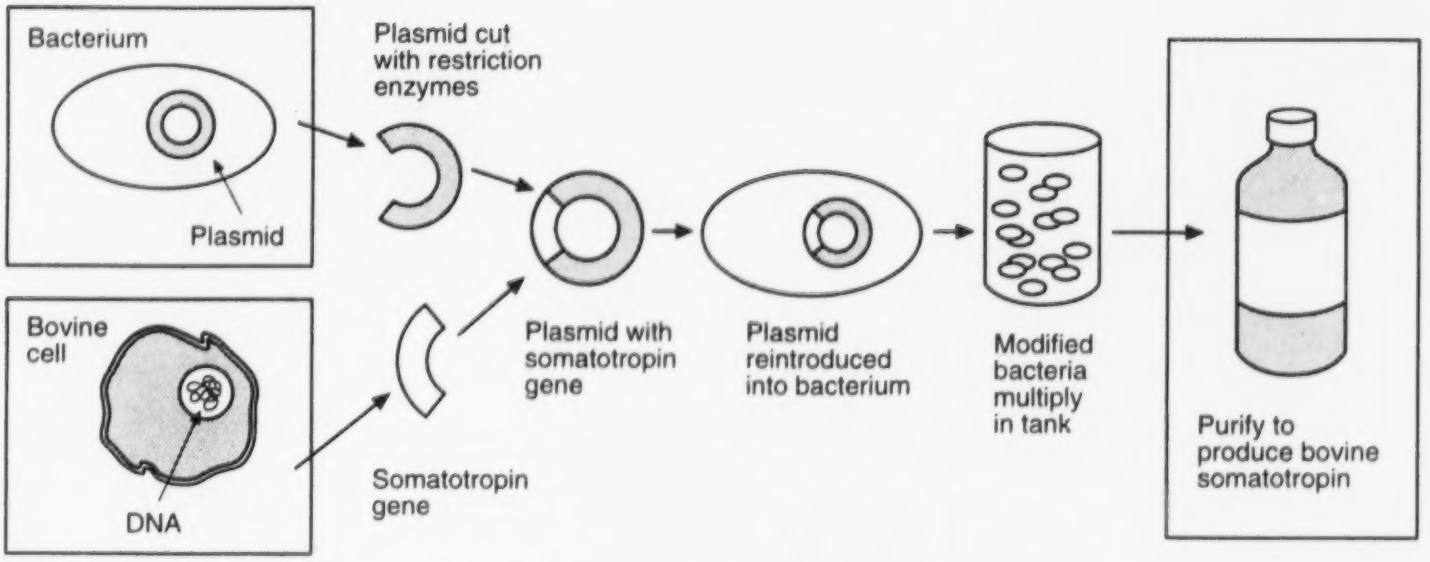
   a. Cloning of adult animals
   b. DNA fingerprinting
   c. Developing tests for diseases
   d. Genetically modifying bacteria

Complete the following short answer questions.

6. How are monoclonal antibodies produced?

7. What two currently emerging applications of biotechnology involve the livestock feed industry?

Producing BST



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Lesson 3: Applications of Biotechnology in Animal Agriculture

Name _____

Emerging Applications of Biotechnology

Objective: Research new applications of biotechnology in animal agriculture.

Working in groups assigned by your instructor, answer the following questions using information from magazines, newspapers, and the Internet.

1. What are some developments that have taken place in the last year in livestock vaccines? (Hint: search for information from companies that produce animal vaccines.)

2. What biotechnology products for feed enhancement are currently available or under development? (Hint: search for information on livestock feed companies or genetically engineered livestock feed.)

3. What is the current status of the use of somatotropin in the livestock industry and the predictions for its use in the future?

4. What are the uses and the expected uses of monoclonal antibodies?

5. What are the latest advances in transgenic livestock?

UNIT V - ANIMAL TECHNOLOGIES

Lesson 4: The Impact of Biotechnology in Animal Agriculture

Objective/Competency: Summarize the impact of biotechnology in animal agriculture.

Study Questions

1. **What are some career opportunities in animal biotechnology?**
2. **What are some economic factors of animal biotechnology that affect producers?**
3. **What are health and safety concerns of consumers of animal biotechnology?**
4. **What are the global social impacts of animal biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit V.
2. Activity Sheet
   a) AS 4.1: Careers in Animal Biotechnology

UNIT V - ANIMAL TECHNOLOGIES

Lesson 4: The Impact of Biotechnology in Animal Agriculture

TEACHING PROCEDURES

A. Review

Animal agriculture is a multibillion dollar industry in the United States. Biotechnology is just beginning to make a substantial impact on this industry. As discussed in the previous lessons, the livestock breeding and animal health sectors of animal agriculture have already felt the impact of biotechnology. As the technology advances, more areas of livestock production will be affected. Advancements in this field will increase the number of career opportunities available. However, the growth of animal biotechnology will bring with it a number of issues that must be resolved, including economic concerns for producers, health and safety concerns for consumers, and global social impacts.

B. Motivation

Some individuals who first entered careers in the computer industry when it was in its infancy in the early 1980s are among the wealthiest people in America today. Bill Gates, the founder of Microsoft, is a good example. Some people have classified biotechnology as the next explosive industry. Career positions in biotechnology are increasing in number between 10 and 20 percent per year. As this industry grows, so will the opportunities for those interested in biotechnology.

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students to list career opportunities related to animal biotechnology. Group these jobs into the eight categories listed below.

What are some career opportunities in animal biotechnology?

a) Research and development
   1) Glass washer
   2) Laboratory assistant
   3) Research assistant
   4) Postdoctoral fellow
   5) Research director/principle investigator

b) Quality control
   1) Quality control analyst
   2) Environmental health and safety specialist
   3) Equipment validation engineer
   4) Validation technician

c) Clinical research
   1) Clinical coordinator
   2) Clinical data specialist
   3) Clinical research associate
   4) Animal handler/technician

d) Manufacturing and production
   1) Product development engineer
   2) Manufacturing engineer/technician
   3) Instrument calibration technician
   4) Packaging operator
e) Regulatory affairs
   1) Regulatory affairs specialist
   2) Documentation specialist
f) Information systems
   1) Scientific programmer analyst
   2) Literature research assistant
g) Marketing and sales
   1) Market research analyst
   2) Sales representative
   3) Customer service representative
h) Administration
   1) Human resources representative
   2) Supply buyer
   3) Patent administrator

2. Ask students to describe how livestock producers decide whether or not to use a new technology. Explain that the economics of using a new product versus not using the product are very important.

What are some economic factors of animal biotechnology that affect producers?

a) Benefit-to-cost ratio of biotechnology products
b) Cost of not using a biotechnology product
c) Reliability of the biotechnology products
d) Cost of additional management or training

3. Ask students to recall the results of the biotechnology opinion survey taken earlier in this course. Have students list some concerns about animal products. Ask students if most people in their community believe that biotechnology is safe.

What are health and safety concerns of consumers of animal biotechnology?

a) Fear of new technology because of a lack of understanding about it
b) Skepticism about safety research
c) Fear about the wholesomeness of foods produced through the use of biotechnology

4. Explain that by the year 2030 the world's population is expected to double to 12 billion people. Ask students to speculate about how food production can be doubled by that year. Ask students to further speculate as to who will be able to obtain food if the demand exceeds the supply.

What are the global social impacts of animal biotechnology?

a) Biotechnology has the potential to increase the global production of meat, dairy products, and eggs.
b) International concerns must be addressed; the international political environment will determine the extent of the use of animal biotechnology.
c) Biotechnology may change the number of livestock producers needed.

F. Other Activities

Have someone with a career in animal biotechnology speak to the class about the job and the field of biotechnology.

G. Conclusion

As biotechnology products such as feed quality enhancers, growth stimulants, protein feeds, and transgenic breeding stock become available to producers, the economic and social impacts of these products will have to be addressed. Career opportunities in animal biotechnology are increasing steadily as the industry expands. Animal biotechnology must, however, address the health and safety concerns of consumers for the products of animal biotechnology to be fully accepted.

H. Answers to Activity Sheet

AS 4.1

Answers will vary.

I. Answers to the Evaluation

1. d
2. c
3. d
4. g
5. b
6. e
7. f
8. a
9. c

10. Consumers are concerned about the new technology because of a lack of understanding about it, skepticism about safety research, and a fear about the healthiness of foods produced through the use of biotechnology.

UNIT V - ANIMAL TECHNOLOGIES Name _____

Lesson 4: The Impact of Biotechnology in Animal Agriculture Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. What is a possible <u>global</u> social impact of biotechnology?

   a. Advancements in biotechnology may decrease the global production of meat, dairy products, and eggs.
   b. Advancements in biotechnology will decrease the costs of management for producers.
   c. Advancements in biotechnology will decrease consumer concerns about the safety of food products.
   d. Advancements in biotechnology may change the number of livestock producers needed.

2. Which of the following is <u>not</u> an economic factor that affects producers?

   a. Reliability of biotechnology products
   b. Cost of not using a biotechnology product
   c. Fear of the new technology
   d. Cost of additional training or management

Match the following positions to the major area of employment by writing the letter from the right-hand column in the correct blank.

3. _____ Research and development	a. Literature research assistant
4. _____ Quality control	b. Animal handler/technician
5. _____ Clinical research	c. Customer service representative
6. _____ Manufacturing and production	d. Postdoctoral fellow
7. _____ Regulatory affairs	e. Product development engineer
8. _____ Information systems	f. Documentation specialist
9. _____ Marketing and sales	g. Equipment validation engineer

Answer the following short answer question.

10. What are health and safety concerns of consumers of animal biotechnology?

Lesson 4: The Impact of Biotechnology in Animal Agriculture

Name _____

Careers in Animal Biotechnology

Objective: Investigate a specific career opportunity in animal biotechnology.

Select a specific job title in the field of animal biotechnology. The careers in this lesson can be used, as well as other titles that you might find. The next step is to compile a profile of the career title you have selected by answering the questions below. Be prepared to present your findings to the class.

1. What are the responsibilities of someone with this job?

2. Where are available jobs located?

3. What is the average salary?

4. What personality traits are needed for someone working in this job?

5. What level of education is needed to obtain this position?

6. Where can this education be obtained?

7. What is the job market like for someone looking for a position?

UNIT VI - PLANT TECHNOLOGIES

Lesson 1: Traditional Plant Breeding

Competency/Objective: Describe traditional plant breeding processes.

Study Questions

1. **What is natural crossbreeding?**
2. **What is selective breeding?**
3. **What are the advantages and disadvantages of selective breeding?**
4. **What is a hybrid?**

References:

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheet
   a) AS 1.1: Hybrids and Their Offspring

UNIT VI - PLANT TECHNOLOGIES

Lesson 1: Traditional Plant Breeding

TEACHING PROCEDURES

A. Introduction

The selection of plants based on phenotypes has been going on for thousands of years. When humans stopped roaming the land and settled in one area, plants that were useful were planted in large quantities and allowed to breed naturally. People then began to notice that some plants were more productive than others, so they saved and grew seeds from these plants, beginning the practice of selective breeding. A major advance in selective breeding occurred in 1922 with the introduction of hybrid seed corn. In the mid-1990s, the first genetically modified crops were introduced, and a new era of plant breeding began.

B. Motivation

Pioneer, DeKalb, and CIBA Seeds are well-known companies that have prospered by developing and marketing selected plant crosses. The sale of seed from these crosses, or hybrids, has yielded many billions of dollars over the last fifty years. These companies spent large sums of money in the 1920s and 1930s on plant breeding programs. In the 1990s, companies like Monsanto have invested billions of dollars in purchasing and developing gene patents and gene transfer technology. Why have companies like Monsanto made these investments?

C. Assignment

D. Supervised Study

E. Discussion

1. Review the parts of a flower, and ask students to recall the ways in which plants reproduce.

   What is natural crossbreeding?

   a) Natural crossbreeding is a reproductive process in which two plant varieties, which have different genotypes, sexually reproduce without human intervention.
   b) It allows the random mixing of genes within a species.

2. Ask students to define what selective breeding is in the livestock industry. Relate this definition to selective plant breeding.

   What is selective breeding?

   a) Selective breeding is the process of identifying plants with desirable traits and causing them to reproduce.
   b) Selective breeding can be done asexually or sexually.
   c) Plants are selectively bred mainly for two reasons.
      1) To increase the production of the useful parts of the plant
      2) To increase the ability of a plant to withstand harsh environments, disease, and plant pests

3. Compare the advantages and disadvantages of selective animal breeding to those of selective plant breeding.

What are the advantages and disadvantages of selective breeding?

a) Advantages
   1) The occurrence of desired plant traits can be increased, especially traits that can raise crop yields.
   2) The performance of a crop is more predictable since the crop of seeds is more uniform.

b) Disadvantages
   1) The occurrence of undesired traits may be increased.
   2) The genetic diversity of a crop species is reduced.
   3) Crop plant uniformity can increase insect problems.

4. Ask students why nearly every producer who plants corn uses hybrid corn. Have students speculate about what a hybrid plant variety is.

What is a hybrid?

a) A hybrid is a plant produced by crossing two inbred lines of plants that are greatly different genetically.

b) Breeders use three common methods of hybrid development.
   1) Single cross - crossing one inbred plant with another
   2) Three-way cross - crossing a single cross with another unrelated inbred plant
   3) Double cross - two single crosses are crossed

c) A hybrid displays extra growth vigor, or hybrid vigor (heterosis); however, it usually either is sterile or produces offspring that do not perform well.

F. Other Activities

Purchase Wisconsin Fast Plants and use them to show several types of selective breeding. Wisconsin Fast Plants grow and produce seed in a very short time so that several generations can be seen in a matter of a few weeks.

G. Conclusion

Since the mid-1980s, the yields of hybrid crops have not increased significantly, which has led some economic analysts to state that traditional hybrids have reached a limit in production capability. The fact that hybrid seed companies are focusing heavily on gene transfer technology for future profit potential further confirms this analysis. Some people disagree with the rationale of this new focus, but this group seems to be in the minority. Traditional plant breeding processes will undoubtably be used in the development of new generations of crop seeds, but the real advances in yield and other desirable crop traits will most likely come from recombinant DNA technology.

H. Answers to Activity Sheet

Students will need guidance as they work through the activity sheet questions. The answers to these questions will vary, but some suggested answers are listed below.

1. How do the growth rates of a hybrid compare with the growth rates of the F_2 of a hybrid?

2. This information will vary but should reveal that F_2 generations of hybrids do not perform as well and that plant-to-plant variations are quite high.

3. Answers will vary but the given hypothesis must be measurable.

4. The experimental group should be defined as the F_2 hybrid group and should consist of a stated number of seeds. The control group is the hybrid seed group; it should also consist of a stated number of seeds.

5. Performance can be measured by the growth of the plant in millimeters per day, the change in the circumference of the stem in millimeters per week, germination rate, and nutrient uptake.

6. Examples include light, temperature, humidity, water, wind/chemical/insect stresses, etc.

7. Answers will vary.

I. Answers to the Evaluation

1. c
2. d
3. d

4. The occurrence of undesired traits may be increased, the genetic diversity of a crop plant population is reduced, and crop plant uniformity can increase insect problems.

5. To increase the production of the useful parts of the plant and to increase the ability of a plant to withstand harsh environments, disease, and plant pests

6. Natural crossbreeding is a reproductive process in which two plant varieties, which have different genotypes, sexually reproduce without human intervention.

7. A hybrid is a plant produced by crossing two inbred lines of plants that are greatly different genetically.

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 1: Traditional Plant Breeding Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Selective breeding can be defined as the:

   a. Process of sexual reproduction of a plant in which pollen from a plant fertilizes the eggs of the same plant.
   b. Crossing of two inbred lines of plants.
   c. Process of identifying plants with desirable traits and causing them to reproduce.
   d. Reproductive process in which two plants with different genotypes reproduce sexually without human intervention.

2. Of the three common methods of producing a hybrid seed, which involves crossing two unrelated inbred plants and then breeding the result with another unrelated inbred plant?

   a. Hybrid cross
   b. Single cross
   c. Double cross
   d. Three-way cross

3. Selective breeding is:

   a. A sexual process.
   b. An asexual process.
   c. Neither a sexual nor an asexual process.
   d. A sexual or an asexual process.

Complete the following short answer questions.

4. What are two disadvantages of selective breeding?

5. Why is selective breeding done?

6. What is natural crossbreeding?

7. What is a hybrid plant?

Lesson 1: Traditional Plant Breeding Name _____

Hybrids and Their Offspring

Objective: Design an experiment that will test the idea that hybrids produce inferior offspring.

For this activity, work in groups assigned by your instructor and design and perform an experiment that will accurately test your hypothesis about the performance of hybrids (F_1) and their offspring (F_2). Use seed collected from a field of hybrid corn and seed from a bag of the same hybrid seed. Whether the offspring of hybrids is "inferior" will be measured by the growth rate of the two groups of plants from emergence to a specified height or length of time as well as the diameter of the stalk, germination rate, and rate of nutrient uptake. The questions below will help guide you through the design of the experiment. Data should be collected periodically until the experiment is completed.

1. What is the problem statement, or what information is desired?

2. List any information that can be collected about the problem. (Hint: check textbooks and the Internet, call a seed salesperson, etc.)

3. State your hypothesis.

4. Define your control and experimental groups. You must consider the size of the groups carefully.

   Experimental group:

   Control group:

5. How will the observations be measured?

6. What environmental controls will be used to ensure that the seed is the only variable in this experiment? (Hint: list the factors that affect the growth rate, and then explain how each factor will be kept the same for the control and experimental group.)

7. What will be the schedule for conducting the experiment? When will observations be made and data be collected?

UNIT VI - PLANT TECHNOLOGIES

Lesson 2: Plant Tissue Culture

Competency/Objective: Explain the process of tissue culture.

Study Questions

1. **What is plant tissue culture?**
2. **What are the advantages and disadvantages of plant tissue culture?**
3. **What equipment is needed for plant tissue culture?**
4. **What steps are involved in plant tissue culture?**
5. **What are the four stages of tissue culture growth?**
6. **How is plant tissue culturing used in genetic engineering?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheets
   a) AS 2.1: Tissue Culturing Strawberries (Instructor)
   b) AS 2.1: Tissue Culturing Strawberries (Student)

UNIT VI - PLANT TECHNOLOGIES

Lesson 2: Plant Tissue Culture

TEACHING PROCEDURES

A. Review

Traditional plant breeding techniques, such as selective breeding, have increased plant quality and production. However, a method of propagation called tissue culture is providing plant breeders with new tools for crop improvement. Tissue culture has not replaced traditional breeding practices but rather has enhanced their effectiveness.

B. Motivation

Plant tissue culture was first used in the early 1970s in the propagation of orchids. The orchid seed is very difficult to sow and germinate. It is not only the smallest seed in the world, but it must be exposed to a specific fungus before it will germinate. To produce an orchid from a seed takes an average of seven years. Tissue culture became the solution to the difficulties of orchid propagation. Today, tissue culture is a commonly used and vitally important method of plant reproduction.

Purchase a miniature plant grown from tissue culture. Use this tiny plant to introduce the basic concept of tissue culture. Every plant cell has the entire genetic code and is capable of producing an entire plant.

C. Assignment

D. Supervised Study

E. Discussions

1. Ask students to define the word tissue. Explain that a tissue is a group of cells that function together for a purpose. Examples of plant tissue include the leaf, stem, root, bud, etc.

   What is plant tissue culture?

   Plant tissue culture can be defined as an asexual method of reproduction in which a piece of a parent plant is placed in a sterile artificial media where it grows into a new plant.

2. Ask students why tissue culture is done. Have students speculate about the advantages and disadvantages of using tissue culture.

   What are the advantages and disadvantages of plant tissue culture?

   a) Advantages
      1) Allows for mass propagation of clones of a desirable plant
      2) Allows the production of pathogen-free plants
      3) Conserves time through the year-round propagation of plants
      4) Conserves growing space
   b) Disadvantages
      1) Requires expensive, sophisticated equipment and facilities
      2) Susceptibility to contamination by microorganisms
      3) Requires skilled workers, which adds to the total cost

3. Show students a petri dish and an autoclave or pressure cooker. Ask students to describe how an autoclave works. Explain that an autoclave uses steam under pressure (approximately 15 psi) to heat items above the temperature that microorganisms can survive.

What equipment is needed for plant tissue culture?

a) Preparation
   1) Refrigerator
   2) pH meter
   3) Scale or balance
   4) Heating plate
   5) Autoclave

b) Transfer
   1) Fume or air flow hood
   2) Forceps
   3) Scalpel
   4) Test tubes or petri dishes
   5) Dissecting microscope

c) Growth
   1) Growth chamber - a room that controls exposure to heat and light

4. Ask students to list the steps of the procedure for tissue culturing.

What steps are involved in plant tissue culture?

a) Media preparation
   1) The growing media for tissue culture varies in composition with the species of plant being used.
   2) Generally the media contains plant nutrients, mineral salts with vitamins, hormones, pure water, sugar, and agar (if a semi-solid media is needed)

b) Selecting and collecting an explant to be cultured
   1) Several types of plant tissues are used for explants.
      (a) Shoot tip
      (b) Bud
      (c) Leaf with veins
      (d) Node
      (e) Bud scale
   2) Rapidly growing tissues are usually preferred for the explant.
   3) Tissue must be healthy and disease free.

c) Cleaning the explant
   1) Plant tissue is disinfected
      (a) Alcohol is used on woody plants only.
      (b) For other plants, the explant is soaked in a 10 percent bleach solution for 10 minutes; plant tissue will be damaged if it is soaked too long.
      (c) A drop or two of detergent is often added to the bleach solution as a wetting agent.
   2) After the tissue is disinfected, it is rinsed in pure water at least three times.

d) Transferring explants to growing media
   1) The explant sections are trimmed and transferred to the growing media; some tissue types are divided for growing more plants.
   2) A dissecting microscope is sometimes needed for very small explant tissues.
   3) This procedure must take place in a sterile environment.

5. Ask students to explain each of the four stages of tissue culture growth.

What are the four stages of tissue culture growth?

a) Initiation and establishment (four to six weeks)
   1) A callus, made of rapidly dividing cells, forms and grows in response to the wounding or cutting of the plant tissue.
   2) Shoots or immature stems begin to grow.

b) Proliferation or multiplication (one to three months)
   1) The shoot multiplies into many shoots.
   2) The new shoots can be divided to increase the number of plants produced.
   3) This stage uses a slightly different growing media.

c) Pretransplant (three weeks)
   1) Roots begin to grow.
   2) A slightly different media is used.
   3) More light is required.
   4) Young plants are stressed slightly in a process called hardening off, in which young plants are exposed to conditions outside the sterile container.

d) Transplanting
   1) The growing plants are put in pots and moved to a shady, humid greenhouse.
   2) The plants are hardened off again and then moved to a regular greenhouse to receive full sun and less humidity.

6. Have students identify reasons that a person or company working with developing transgenic plants would want to use tissue culture.

How is plant tissue culturing used in genetic engineering?

a) Genetically modified plant tissues can be rapidly grown into plants.
b) A large number of plants can be screened for the presence of a desirable trait.

F. Other Activities

1. Demonstrate media preparation.

2. Tissue culture kits and African violet kits are available for purchase from Carolina Biological or Fisher Scientific. Follow the directions on the kits when preparing them.

3. Show the videos *Plant Tissue Culture Part 1 & 2* (VEP) and *Introduction to Plant Tissue Culture* (CEV), all of which are available from MVRC.

G. Conclusion

More than 50 plant species have been genetically modified. In almost every case, tissue culture played an important role in recovering the modified plant tissues. In 1990, more than 300 commercial plant tissue culture labs were in operation. As plant breeders continue to make use of tissue culture techniques, the use of tissue culture will likely increase.

H. Answers to Activity Sheet

I. Answers to the Evaluation

1. b
2. d
3. c
4. b
5. c
6. c

7. d

8. Plant tissue culture can be defined as an asexual method of reproduction in which a piece of a parent plant is placed in a sterile artificial media where it grows into a new plant.

9. Tissue culturing is used in genetic engineering to rapidly grow genetically modified plant tissues into plants and to screen a large number of plant tissues for the presence of a desirable trait.

10. Students may list any two of the following: refrigerator, pH meter, scale or balance, heating plate, autoclave, fume or air flow hood, forceps, scalpel, petri dishes or test tubes, dissecting microscope, or growth chamber.

Name _____

Lesson 2: Plant Tissue Culture

Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following statements is not an advantage of tissue culture?

   a. Tissue culture allows for the mass propagation of clones.
   b. Plant tissue cultures are susceptible to contamination.
   c. Plant tissue culture allows for the production of pathogen-free plants.
   d. Plant tissue culture allows for the propagation of plants year round.

2. Which of the following substances is not commonly used to make a tissue culture media?

   a. Sugar
   b. Mineral salts with vitamins
   c. Plant hormones
   d. A dilute sodium chloride solution

3. Which of the following is an important criterion to consider when selecting an explant?

   a. The explant should be selected from a young parent plant.
   b. The parent plant should be a monocot because dicot plants do not give good explants.
   c. The explant should be taken from a healthy, rapidly growing part of the parent plant.
   d. The explant is always taken from the shoot tip of the parent plant.

4. If it is not woody plant tissue, the selected explant is disinfected with:

   a. Alcohol.
   b. 10 percent bleach solution.
   c. A detergent.
   d. A very weak acid solution.

5. In which stage of plant tissue growth do the roots begin to form and grow?

   a. Initiation and establishment
   b. Proliferation or multiplication
   c. Pretransplant
   d. Transplanting

6. The stage in which the shoot begins to grow is called the:

   a. Transplanting stage.
   b. Proliferation or multiplication stage.
   c. Initiation and establishment stage.
   d. Pretransplanting stage.

7. A callus is a:

   a. Mass of dead plant cells that accumulate as the tissue culture grows.
   b. Group of cancer cells that can destroy a plant tissue culture.
   c. Group of old cells that forms when the incorrect part of the plant is selected for the explant.
   d. Group of rapidly dividing cells that is a response to the wounding of plant tissue.

Complete the following short answer questions.

8. What is plant tissue culture?

9. How is plant tissue culture used in genetic engineering?

10. What are two pieces of equipment used in tissue culture?

Lesson 2: Plant Tissue Culture Name _____

Tissue Culturing Strawberries

Objective: Perform plant tissue culture.

Materials and Equipment:

1 medium-sized stainless steel pan
1 long-handled spoon
1-2 glass test tubes with caps (25 x 100 mm)
Test tube racks
2 gallons of sterile distilled bottled water
1 glass (Pyrex) quart pitcher or old coffee pot
1 pressure cooker
2-4 eight-inch forceps
1 sharp knife or scalpel
Parafilm™ or clear tape
Rubber or latex gloves
20 ml of 1N NaOH
20 ml of 1N HCl
2 eyedroppers
1 plastic graduated cylinder
1 small bottle of household bleach
2 packages of premixed powder tissue culture medium (shoot multiplication media and pretransplant media)
1 package of agar
1 package of litmus paper (3.5-6.8) or a pH meter
2-4 medium-sized plastic containers
2-3 sterile paper towels (made by rolling them up in aluminum foil and sterilizing them in the pressure cooker)
1 72-hole seedling tray (11 x 22)
Shelves lighted by cool white fluorescent lights
1 transfer chamber (It can be made from wood or cardboard with a clear plastic sheet or plexiglass over the front and top of the chamber. Holes should be cut in the front so that both hands can be used to work inside the chamber.)
10-20 strawberry runner tips (about 1 inch long)

Procedure for Media Preparation:

1. Follow the directions on the prepackaged shoot multiplication media mix to prepare the media. About one liter of media is enough for the entire class. Make sure that a 2-liter container or larger is used when mixing the media since it can boil up and spill. Add the powder mix to the water (not the reverse). Stir the mixture.

2. Next, the pH of the mixture must be adjusted to 5.7. Measure the pH of the solution with litmus paper. If the solution has a pH higher than 5.7, add one drop of HCl and stir the solution. If, however, the solution has a pH lower than 5.7, add one drop of NaOH and stir. This process is repeated until the pH is 5.7.

3. Thicken the mix by adding agar. Approximately 5 grams of agar are needed per liter of solution. After the agar is stirred into the solution, heat it and stir until the solution becomes clear. Transfer the hot solution to the glass pitcher and then carefully pour it into the test tubes.

4. Sterilize the medium in a pressure cooker for about 15 minutes. When sterilizing test tubes holding media, place them in a wide-mouth jar or tie them in bundles of ten so that they stand up in the pressure cooker.

Lesson 2: Plant Tissue Culture Name _____

Tissue Culturing Strawberries

Objective: Perform plant tissue culture.

Materials and Equipment:

1 medium-sized stainless steel pan
1 long-handled spoon
1-2 glass test tubes with caps (25 x 100 mm size)
Test tube racks
2 gallons of sterile distilled bottled water
1 glass (Pyrex) quart pitcher or old coffee pot
1 pressure cooker
2-4 eight-inch forceps
1 sharp knife or scalpel
Parafilm™ or clear tape
Rubber or latex gloves
20 ml of 1N NaOH
20 ml of 1N HCl
2 eyedroppers
1 plastic graduated cylinder
1 small bottle of household bleach
2 packages of premixed powder tissue culture medium (shoot multiplication media and pretransplant media)
1 package of agar
1 package of litmus paper (3.5-6.8) or a pH meter
2-4 medium-sized plastic containers
2-3 sterile paper towels (made by rolling them up in aluminum foil and sterilizing them in the pressure cooker)
1 72-hole seedling tray (11 x 22)
Shelves lighted by cool white fluorescent lights
1 transfer chamber (It can be made from wood or cardboard with a clear plastic sheet or plexiglass over the front and top of the chamber. Holes should be cut in the front so that both hands can be used to work inside the chamber.)
10-20 strawberry runner tips (about 1 inch long)

Procedure:

A. Selecting and Cleaning the Explants

1. Select a healthy-looking strawberry runner tip on which the bud has not yet opened. Cut off 1 to 1 1/2 inches of the tip and place it in a plastic bag containing a damp paper towel.

2. Fill a wide-mouth jar with 1/2 pint of sterile water. Add 2 or 3 drops of liquid dishwashing detergent. Place the runner tips in the jar, put the lid on, and vigorously shake the jar for 1 minute. Pour out the water and rinse the runner tips 2 or 3 times with sterile water. Repeat this process, or dip the runner tips in 70 percent alcohol for only a few seconds and then rinse 2 to 3 times with sterile water.

3. In another container, add 30 ml of bleach to 270 ml of sterile water to yield a 10 percent bleach solution. Add 2 drops of the detergent and place the explant in the solution. Shake for 10 seconds every minute for ten minutes. Quickly drain the solution; add sterile water and shake the container.

B. Transferring the Explants

1. Spray and wipe down all the inside surfaces of the transfer chamber with a 10 percent bleach solution. Allow them to air dry. Place a small container of 10 percent bleach solution and another container of 1 percent bleach solution in the transfer chamber to use for sterilizing the instruments and gloved hands. Place the forceps and knife in the 10 percent bleach solution and then in the 1 percent solution. Lay the sterilized instruments on a sterile paper towel and allow them to air dry.

2. Using the forceps, unroll another paper towel on the work area inside the transfer chamber. Use the forceps to place the runner tip on the towel. Hold the tip with the forceps while picking up the knife or scalpel and cutting off 1 cm of the stem. Put the knife in the 10 percent bleach solution. Pick up a test tube of medium while holding the explant with the forceps. Remove the test tube cap with the small finger of one hand and hold it firmly in place while putting the cut explant on the medium. Cap the test tube and seal it with Parafilm™ or tape.

C. Growing the Cultures

1. Place the test tube in the planter tray or another holder on a shelf under a florescent light that is 8 to 10 inches away. Continuous light may be used, but if a timer is available, 16 hours of light is normal. Plants may remain at room temperature.

2. Check the cultures every day for signs of contamination. If any fungus or other form of contamination is present, sterilize the contaminated test tubes before discarding.

3. Transfer the explant to new medium every two weeks until it is growing well.

4. In one to two months, the explants should have many shoots and can be divided. When shoots are observed, divide the explant into two pieces about 0.5 cm in diameter. Repeat this process until enough growing plants are produced. Transfer them to a pretransplant medium that has no hormones.

5. After two to four weeks on the medium, the roots should develop. Transplant the plants to an artificial soil mix (greenhouse mix) in a seedling tray. Cover them with transparent plastic and place on a lighted shelf or in a shaded greenhouse.

6. After two or three weeks, uncover the tray daily for a length of time. Gradually increase the time it remains uncovered for a week until they are no longer being covered.

UNIT VI - PLANT TECHNOLOGIES

Lesson 3: Genetically Modified Plants

Competency/Objective: Describe current applications of biotechnology in plants.

Study Questions

1. **How are genetically altered plants developed?**
2. **How do herbicide-tolerant plants function?**
3. **How do insect-resistant plants function?**
4. **How do disease-resistant plants function?**
5. **What effect has biotechnology had on food quality and processing?**

References

1. *Biotechnology:Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheet
   a) AS 3.1: The Current State of Plant Biotechnology

UNIT VI - PLANT TECHNOLOGIES

Lesson 3: Genetically Modified Plants

TEACHING PROCEDURES

A. Review

Lesson 2 discussed the procedure of plant tissue culture and its use in reproducing plants. This lesson will address producing plants that have been genetically modified. Plant breeders have always searched for healthier and more productive plants. With the development of recombinant DNA technology, plant breeders have been able to select traits from sources outside the plant species with which they are working. As the vast selection of plants, animals, and microbes is examined for potentially helpful genes, researchers will continue discovering and using new genes to increase the world's crop production and decrease the cost of production.

B. Motivation

How valuable is the development of insect- or disease-resistant plants? The global cost of the current chemical control of insects and fungal diseases is $8.7 billion. However, even with the use of these chemical controls, insects and disease cause a 12 to 13 percent reduction in crop production. The chemical insecticide and crop loss costs associated with the Colorado potato beetle and the corn rootworm are over $1 billion in the United States alone. Insect damage costs for cotton exceed $645 million. Obviously, the added costs of genetically modifying a crop to be resistant to one of these pests may be easily offset by the decrease in chemical costs and the increase in yield.

C. Assignment

D. Supervised Study

E. Discussion

1. Review with students the methods of genetically modifying animal cells. Ask students to recall the differences between animal and plant cells, especially the presence of the cell wall. Explain that the cell wall of a plant requires that a forceful method of gene insertion be used.

   How are genetically altered plants developed?

   a) The desired gene or genes for a trait must be found, isolated, and cloned.
   b) A method of genetic transfer is selected.
      1) Bacteria or virus
         (a) The desired gene and a marker gene is inserted into the bacterium or virus, and the microorganism is placed in contact with the plant cell to be modified.
         (b) The organism infects the cell and transfers the desired gene.
      2) Gene gun
         (a) The desired gene and a marker gene are inserted into a plasmid.
         (b) The plasmid is placed on the surface of very small (1 mm in diameter), heavy metal (gold) pellets.
         (c) These pellets are shot into the plant cells with the use of a small high-pressure gun.
      3) Chemicals
         (a) The cell wall is weakened or dissolved.
         (b) The desired gene is physically placed in the cell.
         (c) The plant cell is stimulated to repair the cell wall.

c) Plant cells that incorporate the desired gene into their DNA are selected (by looking for the marker gene) and grown into mature plants through the use of tissue culture.

2. Ask students to list some commonly used herbicides. How do these chemicals kill weeds? The answer lies in the fact that an important chemical process of the plant is disrupted by the herbicide.

How do herbicide-tolerant plants function?

a) Herbicides kill plants by chemically blocking a metabolic pathway.
b) Herbicide-tolerant plants have the ability to bypass the blocked portion of the metabolic pathway; this ability comes from genes that produce certain enzymes that provide a different chemical route around the blocked portion.

3. Explain to students that plants have very little natural resistance to insects and that many insects are becoming increasingly resistant to chemical insecticides. Explain the source of resistance (*Bt*) of insect-resistant plants.

How do insect-resistant plants function?

a) *Bacillus thuringiensis (Bt)* is a soil bacterium that produces a protein that, when eaten by specific insects, dissolves the wall of the gut, causing the insect to be unable to eat and eventually to die.
b) Each *Bt* strain kills a specific type of insect.
c) The genes that cause the production of the protein in specific *Bt* strains have been isolated and transferred to several crop plants, including potatoes, corn, and cotton.

4. Point out that plant diseases are commonly caused by viruses, bacteria, and fungi. Explain how disease-resistant plants combat them.

How do disease-resistant plants function?

a) Virus-resistant plants - A small portion of the DNA from the virus is inserted into the plant DNA, giving the plant an immunity to the virus.
b) Bacteria- and fungus-resistant plants - Current research in this area centers on trying to enhance the plant's natural immune response; plants resistant to bacteria and fungi are not currently available.

5. Ask students if they have heard of or tasted a FlavrSavr™ tomato. Explain that the quality and processing of foods is being advanced by biotechnology.

What effect has biotechnology had on food quality and processing?

a) Tomato
   1) The FlavrSavr™ tomato was developed by Calgene to have a vine-ripened taste and a longer shelf life.
   2) Genes were inserted into the tomato plant that cause the production of an enzyme that slows the breakdown of pectin, which keeps the tomato from getting soft and rotting.
   3) Four other companies have gained approval for similar genetically modified tomatoes.
b) Modified canola and corn plants - These plants yield a grain that is higher in oil content and has a modified oil composition in which the level of saturated and unsaturated oil has been changed to meet different uses.
c) High-starch potatoes
   1) The potatoes are higher in starch and lower in water content.
   2) When chips or french fries are made, they will absorb less oil and will therefore be lower in fat.

F. Other Activities

Plant some genetically modified Roundup Ready™ soybeans from Monsanto and some soybean seeds that are the result of a hybrid cross. When the plants reach 8 to 10 inches in height, spray the plants with Roundup. Have the students record daily observations of the effects of the Roundup on both types of plants.

G. Conclusion

The development of transgenic plants by private companies has been fueled by the potential for large profits. Producers are willing to pay companies a premium for crop seed that can lower the costs of raising a crop. The potential of genetically engineered plants is only beginning to be realized.

H. Answers to the Activity Sheet

AS 3.1

Answers will vary based on available information.

I. Answers to the Evaluation

1. a
2. b
3. d
4. a

5. *Bt* or *Bacillus thuringiensis* is a soil bacterium that produces a protein that when eaten by specific insects causes the insect's gut wall to dissolve; it eventually dies. The genes in specific *Bt* strains that cause the production of the protein have been isolated and transferred to several crop plants.

6. Students may list any one of the following: the FlavrSavr™ tomato developed to have a vine-ripened taste and a longer shelf life, modified canola and corn plants that yield a grain that is higher in oil content and has a modified oil composition, and high-starch potatoes that are higher in starch and lower in water content.

7. Students should list the following steps.

   a. The desired gene must be found, isolated, and cloned.
   b. A method of genetic transfer is selected. A bacteria or virus, a gene gun, or a chemical that dissolves or weakens the cell wall is used.
   c. Plant cells that incorporate the desired gene into their DNA are selected by looking for the marker gene and grown into mature plants through the use of tissue culture.

Name _____

Lesson 3: Genetically Modified Plants

Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is not a method of transferring DNA into a plant cell?

   a. Using two electrical probes that cause the desired DNA to be forced into the targeted plant cell
   b. Chemically weakening or dissolving the cell wall and inserting the DNA
   c. Using a gene gun that fires heavy metal pellets coated with DNA
   d. Using bacteria and viruses containing the desired gene that attack the targeted cell

2. What is the name of a piece of DNA located or placed near a targeted section of DNA that helps in the identification of the targeted section?

   a. Plasmid DNA
   b. Marker gene
   c. Targeted DNA
   d. Signal gene

3. How do herbicide-tolerant soybeans tolerate the active chemical in a herbicide?

   a. The gene added to the soybeans prevents the absorption of the chemical.
   b. The gene added to the soybeans accelerates the natural immune system of the soybean plant to ward off the toxic effect of the chemical.
   c. The gene added to the soybeans chemically reacts with the substance to neutralize it.
   d. The gene added to the soybeans produces an enzyme that provides a way around the herbicide-caused metabolic pathway block.

4. The common soil bacteria, *Bacillus thuringiensis*, has played a big role in the development of:

   a. Insect-resistant plants.
   b. Disease-resistant plants.
   c. Herbicide-tolerant plants.
   d. High-starch potatoes.

Complete the following short answer questions.

5. How do insect-resistant plants function?

6. What is one example of a biotechnology product that enhances food quality and/or processing? What aspect of the product has been changed through biotechnology?

7. What are the three steps in the development of a genetically modified plant? Briefly describe each step.

a.

b.

c.

Lesson 3: Genetically Modified Plants Name _____

The Current State of Plant Biotechnology

Objective: Describe the current state of plant biotechnology.

Answer the questions below. The Internet would be the best research tool, but newspapers and magazines may also be used. If additional information about plant biotechnology is found, summarize this information on the back of this activity sheet. You will be asked to share some of this information with the class.

1. List at least six companies that are involved developing products in plant biotechnology **and** one of the newest products from each company.

   a.

   b.

   c.

   d.

   e.

   f.

2. Briefly describe how one of these products was developed. (Include information on the source of the transferred gene.)

3. What genetically modified plants have been recently approved by the USDA, FDA, and EPA?

4. What do farm-related magazines have to say about the future of genetically engineered plants/crops?

4. What are farm-related magazines saying about the future of genetically engineered plants/crops?

UNIT VI - PLANT TECHNOLOGIES

Lesson 4: Emerging Applications of Plant Biotechnology

Competency/Objective: Identify emerging applications of biotechnology in plants.

Study Questions

1. **What are biofuels?**

2. **What are biopolymers?**

3. **What are some traits that producers desire in plants?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.

2. Activity Sheet

   a) AS 4.1: Designer Plants--The Agricultural Products of the Future

Lesson 4: Emerging Applications of Plant Biotechnology

TEACHING PROCEDURES

A. Review

Plants have been cultivated for centuries to provide food for both humans and animals. An increasing number of plants are now grown for industrial and medical uses as well. As discussed in Lesson 3, plants can be genetically modified to improve their usefulness for these purposes. Just as George Washington Carver discovered more than a hundred uses for peanuts, so to are today's scientists discovering new uses for plants, especially modified plants. Some emerging applications of plant biotechnology will be examined in this lesson.

B. Motivation

Pass out one soybean-derived crayon, labeled "A," and one traditional crayon, labeled "B," to three or four students. Ask these students to evaluate the two crayons and determine which one is better. List their comments on the board. Ask students if any of them know any young children who play with crayons. Have they ever seen them chew on or simply eat a crayon? Tell the class that one of the crayons is safe to eat. Increase student interest by telling the class that one of the two crayons earned four college students more that $100,000 and prompted many offers of high-paying jobs. Explain that the four college students won a contest sponsored by the United Soybean Board by developing soybean-based crayons. Talk about how a problem relevant to one of those college students (his younger brother eating crayons) sparked a new use for a traditional crop plant.

Pass around a piece of soybean "marble" and explain that a fifth-grader discovered this product. She was trying to come up with a project for her school science fair. She mixed glue and newspaper in a blender and then heated it in the microwave. The mixture formed a hard, granite-like block that could be worked like wood. The formula has been changed slightly, with the glue being replaced by a product made from soy flour, and her discovery is now being marketed as a building material.

Point out that the genetic engineering of plants provides researchers the opportunity to modify a plant so that it is better suited for a particular application. Therefore, more plant-derived products like these will probably be developed, and existing products will likely be enhanced.

C. Assignment

D. Supervised Study

E. Discussion

1. Show a sample of biodiesel to the class and ask students how it is made. Ask students to list other plant-derived fuels.

   What are biofuels?

   a) Biofuels are combustible substances derived from organic sources. Nearly all biofuels are derived from plants.
   b) Several types of biofuels exist.
      1) Alcohol-based fuels
         (a) These fuels are made by fermenting plant materials.
         (b) An example is gasohol, a fuel that is 10 percent alcohol and 90 percent gasoline.

(c) Researchers are searching for plants that they can modify to produce ethanol more economically.

2) Plant oil-based fuels, or biodiesels
   (a) These fuels are made from seeds with a high oil content.
   (b) Most are the result of the addition of methanol to the plant oil and the removal of a sticky substance called glycerine.
   (c) Soybean and rapeseed oils are most commonly used.
   (d) Scientists are looking for ways to engineer plants to produce a larger quantity of oil and to require less extensive processing.

3) Biogas fuels
   (a) Methane gas is derived from the anaerobic (oxygen-free) digestion of plant materials and/or animal waste by microorganisms.
   (b) Researchers are examining the possibility of developing plants that would produce crop residue that is more useful for methane production.

2. Ask a student to look up the definition of a polymer (a natural or synthetic substance that is formed by joining many simple molecules to form large molecules) and read it to the class. Then ask the students to speculate about the definition of a biopolymer.

What are biopolymers?

a) Biopolymers are complex chemical compounds produced by living things; biopolymers from genetically engineered plants may be useful in a variety of industries.
b) Biotechnology is being applied to develop five different types of biopolymers.
   1) Carbohydrates - Researchers are working on the development of a modified corn starch that does not break down when heated in the microwave and genetically engineered potato plants with leaves that have a high sugar content.
   2) Fatty acids - Scientists are working on modifying corn and canola oils to contain a high level of either saturated or unsaturated fatty acids depending on which is needed for a given application.
   3) Pharmaceutical proteins - These biopolymers are used for human health products.
   4) Industrial enzymes - Scientists are trying to modify plants to provide enzymes at a low price for purposes such as fermentation for brewing, processing and bleaching paper, and a feed additive to aid in digestion in livestock.
   5) Bioplastics - Scientists are attempting to develop plants with tissues that contain a higher level of the chemical components of plastic.

3. Ask students to use their imaginations and list the characteristics (other than increased yield) that they think would be valuable plant traits. Some of the traits listed are more than likely being researched as possible crop enhancements. Have students complete AS 4.1. Divide the class into groups of three or four students. Assign two or three sectors of the agricultural industry (based on the FFA proficiency award areas) to each group. Have students use any available resources, including textbooks, magazines, and the Internet. Encourage the group members to pick different questions to research and then compile all of the answers. The answers that the students come up with should be rational, but encourage them to use their imaginations as well as their resources.

What are some traits that producers desire in plants?

a) Environmentally tolerant plants
   1) Drought-tolerant plants
   2) Frost-tolerant plants
   3) Salt-tolerant plants
b) Forestry products
   1) Stronger wood
   2) Fire-resistant wood
   3) Trees that grow more quickly

c) Food products with an improved taste
   1) Sweet corn and peas that stay sweet longer
   2) Naturally decaffeinated coffee
d) Fiber crops such as naturally colored and fade-resistant cotton

F. Other Activities

1. Have students search the Internet looking for emerging applications of plant biotechnology.

2. Have students compete in the Missouri Department of Agriculture New Product Contest using products created with biotechnology.

G. Conclusion

Biofuels, biopolymers, and specialized plants with traits desired by producers are three major emerging applications of plant biotechnology. As information about the vast quantity of genes available from microbes, animals, and plants increases, more and more specialty crop plants will be developed. Most of these crops will comprise only a fraction of plant agriculture, and demand will determine which crops are grown.

H. Answers to the Activity Sheet

AS 4.1

Answers will vary.

I. Answers to the Evaluation

1. c
2. d
3. e
4. b
5. a
6. a
7. d
8. Stronger wood, fire-resistant wood, and trees that grow more quickly
9. Drought-tolerant plants, frost-tolerant plants, or salt-tolerant plants

Name _____

Lesson 4: Emerging Applications of Plant Biotechnology

Date _____

EVALUATION

Match the examples of biopolymers with their descriptions.

1. _____ These biopolymers are used in the bleaching of paper and as additives to animal feeds.
2. _____ This type of biopolymer is found in modified oils from corn or canola.
3. _____ Scientists are attempting to change the chemical components of plants to contain higher levels of substances used for these biopolymers.
4. _____ These biopolymers are used for human health products.
5. _____ This group of biopolymers consists of products like a modified corn starch that does not break down when heated in the microwave.

a. Carbohydrates
b. Pharmaceutical proteins
c. Industrial enzymes
d. Fatty acids
e. Bioplastics

Circle the letter that corresponds to the best answer.

6. Which of the following is <u>not</u> a type of biofuel for which genetically modified plants are being developed?

   a. Petroleum-based fuel
   b. Alcohol-based fuel
   c. Plant oil-based fuel
   d. Biogas fuel

7. Biopolymers are:

   a. Complex carbon compounds that are byproducts of many types of plant biotechnology research.
   b. Combustible substances derived from plants or animals.
   c. Inorganic chemicals that cause plants to mutate.
   d. Complex chemical compounds from genetically engineered plants that are useful in many industries.

Complete the following short answer questions.

8. What are three products that the forestry industry would like biotechnology researchers to develop?

9. What are three types of environmentally tolerant plants that scientists are researching?

Lesson 4: Emerging Applications of Plant Biotechnology Name _____

Designer Plants--The Agricultural Products of the Future

Objective: Describe products of plant biotechnology that could be a part of the future of agriculture.

Answer the following questions to describe a possible plant product produced through biotechnology that might be used in one of the sectors of agriculture assigned to you by your instructor. You will need to use resources like textbooks, magazines and the Internet along with your imagination to complete this assignment.

1. Which sector of agriculture were you assigned?

2. What are the problems or limitations in raising plants used in this sector? (Include anything that costs money or time to control or overcome.)

3. What traits are currently being researched that may help improve the plants used in this agricultural sector?

4. What traits could be added to a plant that would not affect its main use but would improve its secondary uses or byproducts?

5. What are some industrial proteins that could be produced with plants in this sector of agriculture?

6. What are some traits that might enhance the aesthetic appeal (desirability) of plant products in this sector?

7. What is one trait that you feel will be developed in the next ten years?

UNIT VI - PLANT TECHNOLOGIES

Lesson 5: The Impact of Plant Biotechnology

Competency/Objective: Summarize the impact of biotechnology in plant agriculture.

Study Questions

1. **What are the career opportunities in plant biotechnology?**
2. **What are some economic factors of plant biotechnology that affect producers?**
3. **What are health and safety concerns of consumers of plant biotechnology?**
4. **What are the global social impacts of plant biotechnology?**

References

1. *Biotechnology: Applications in Agriculture (Student Reference).* University of Missouri-Columbia: Instructional Materials Laboratory, 1998, Unit VI.
2. Activity Sheet
   a) AS 5.1: Careers in Plant Biotechnology

UNIT VI - PLANT TECHNOLOGIES

Lesson 5: The Impact of Plant Biotechnology

TEACHING PROCEDURES

A. Review

Plant biotechnology has many applications, not only for food, but for products such as biofuels and biopolymers, as discussed in the last lesson. Many of these products may be on the market soon. What will be the impact of these new products? Will they only be positive? This lesson will provide a look at the economic, health and safety, and social effects of biotechnology on the United States and the world.

B. Motivation

Ask students to imagine this headline "World Price of Sugar Drops to All-Time Low: New Sugar-Producing Tobacco Provides Bumper Crop." Discuss the global effects of this event.

C. Assignment

D. Supervised Study

E. Discussion

1. Ask students to recall the career areas discussed for animal biotechnology. Relate them to plant biotechnology, pointing out those careers specific to plant biotechnology.

What are career opportunities in plant biotechnology?

a) General areas of biotechnology career opportunities
   1) Research and development
   2) Quality control
   3) Clinical research
   4) Manufacturing and production
   5) Regulatory affairs
   6) Information systems
   7) Marketing and sales
   8) Administration

b) Career opportunities specific to plant biotechnology
   1) Plant scientist
   2) Greenhouse manager
   3) Tissue culture technician

2. Ask students to list the benefits and risks of producing a genetically modified crop.

What are some economic factors of plant biotechnology that affect producers?

a) Benefits
   1) Lower input costs for crops that require less chemicals
   2) Premium price for specialized crops

b) Drawbacks
   1) Higher price of seed
   2) Higher costs associated with the special handling needed to keep crops with a modified composition separate from unmodified crops
   3) Limited market for specialized crops

3. Ask students to recall the results of the survey done in Unit 2. Have students list any concerns raised by those who were surveyed.

What are health and safety concerns of consumers of plant biotechnology?

a) Questions about the healthiness of genetically modified foods arise about foods in which the composition of the plant is changed.
b) Some consumers also worry that a plant altered for an industrial purpose will wind up in the food supply.

4. Ask students to speculate about the effect on other countries if a transgenic crop is introduced in the United States. Ask students if the effect would be positive or negative.

What are the global social impacts of plant biotechnology?

a) Positive global impacts
    1) Transgenic plants, such as the sweet potato resistant to the feathery mottle virus (FMV), can greatly benefit developing countries.
    2) The development of environmentally tolerant plants could help reduce the risk of famine in some countries.
    3) The development of edible plant vaccines could make it possible for millions of poor people to receive vaccines.
b) Negative global impacts - The development of some genetically modified crops can destroy the profitability of agricultural cash crops that may be vital to a country's economy.

F. Other Activities

Have students give presentations on the possible social impacts of the introduction of a new transgenic plant.

G. Conclusion

Transgenic crops are just beginning to be planted by producers, and therefore the full impact of these new crops is not quite clear. What transgenic plants will be introduced in the next five to ten years? What will be the long-term impact of the transgenic crops already in commercial production? Will producers, consumers, and developing countries be positively or negatively affected by plant biotechnology? These questions are difficult to answer, but they must be addressed to avoid social and economic pitfalls.

H. Answers to the Activity Sheet

AS 5.1

Answers will vary.

I. Answers to the Evaluation

1. a
2. d

3. Students may list either of the following: the healthiness of genetically modified foods in which the composition of the plant is changed or that a plant altered for an industrial purpose will wind up in the food supply.

4. Reduced input costs for crops that require less chemicals and a premium price for specialized crops

5. Plant scientist, greenhouse manager, tissue culture technician

UNIT VI - PLANT TECHNOLOGIES Name _____

Lesson 5: The Impact of Plant Biotechnology Date _____

EVALUATION

Circle the letter that corresponds to the best answer.

1. Which of the following is a positive development in plant biotechnology for developing countries?

   a. The development of transgenic plants such as the FMV-resistant sweet potato
   b. The development of corn modified for industrial purposes
   c. The development of modified potatoes with leaves that can produce a large amount of sugar
   d. The development of a modified canola oil that can replace more expensive tropical oils

2. What is a potential drawback for producers raising genetically modified crops?

   a. Some genetically modified crops can reduce input costs for producers.
   b. Most genetically modified crops require more rain to grow than unmodified crops.
   c. Producers can normally obtain a higher price for crops with a modified composition.
   d. Specialized crops produced through genetic modification may have limited markets.

Complete the following short answer questions.

3. What is one health or safety concern that some consumers have about plant biotechnology?

4. What are two economic advantages that modified crops could have for producers?

5. What are three career opportunities <u>specific</u> to the field of plant biotechnology?

Lesson 5: The Impact of Plant Biotechnology Name _____

Careers in Plant Biotechnology

Objective: Investigate a specific career opportunity in plant biotechnology.

Select a specific job title in the field of plant biotechnology. The careers listed in this lesson can be used, as well as other job titles that you might find. Compile a profile of the career by answering the following questions. Then report your findings to the class.

1. What are the responsibilities of someone with this job?

2. Where are available jobs located?

3. What is the average salary?

4. What personality traits are valuable for someone working in this job?

5. What level of education is needed to obtain this position?

6. Where can this education be obtained?

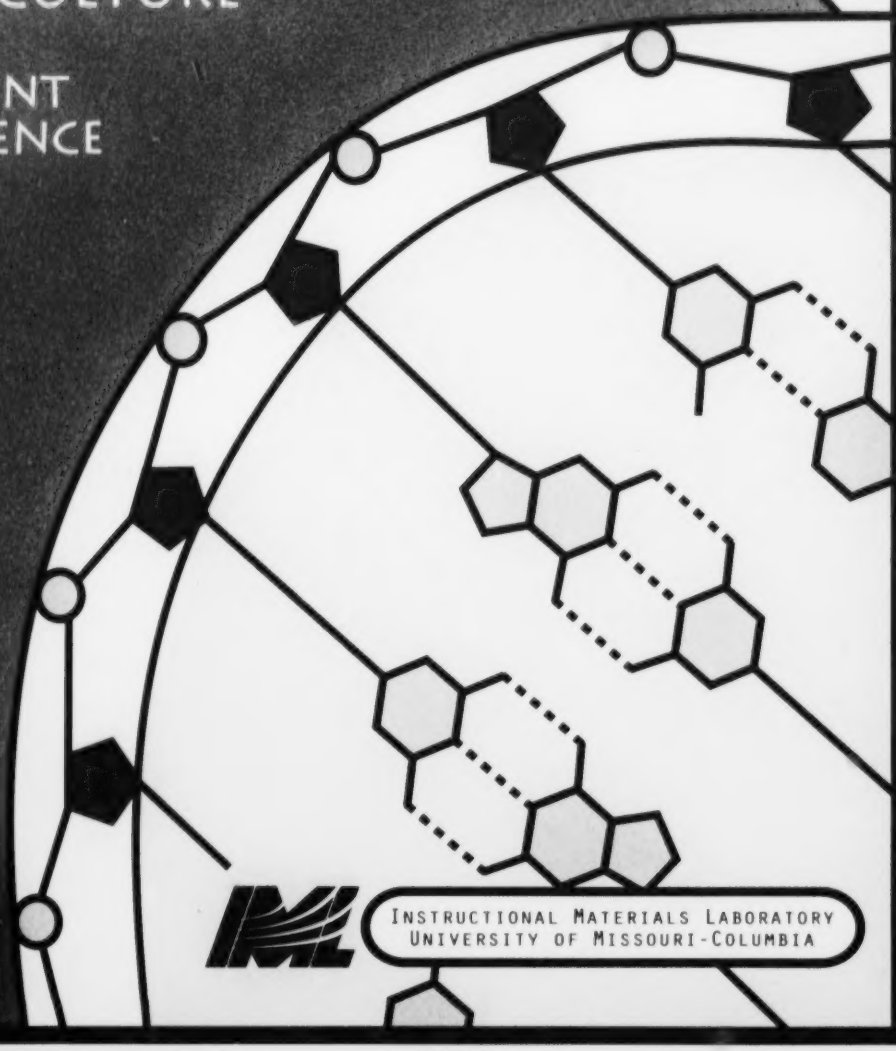
7. What is the future job market outlook like for this position?

10-1029-S

BIOTECHNOLOGY

APPLICATIONS IN AGRICULTURE

STUDENT REFERENCE



In cooperation with
Agricultural Education
College of Agriculture, Food and Natural Resources
University of Missouri-Columbia

In cooperation with
Agricultural Education Section
Division of Vocational and Adult Education
Elementary and Secondary Education
Jefferson City, Missouri

Instructional Materials Laboratory
University of Missouri-Columbia

Student Reference

BIOTECHNOLOGY: APPLICATIONS IN AGRICULTURE

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Volume 30
Number 10

Catalog Number 10-1029-S
March 1998

Available from:
Instructional Materials Laboratory
University of Missouri-Columbia
10 London Hall
Columbia, MO 65211
573-882-2883

The activity that is the subject of this report was supported in whole or in part by funds from the Department of Elementary and Secondary Education, Division of Vocational and Adult Education. However, the opinions expressed herein do not necessarily reflect the position or policies of the Missouri Department of Elementary and Secondary Education or the Division of Vocational and Adult Education, and no official endorsement should be inferred.

ACKNOWLEDGMENTS

Recognition is given to the following advisory committee members for providing their valuable time and suggestions in developing this curriculum. The committee consisted of Jeff Kitchen, Jim Welker, Kristen Kingsland, Marvin Hoskey, Richard Norris, Corey Mouser, Chris Stockhorst, Phil Fox, Richard Asbill, Aaron Nevils, and Delbert Lund.

Appreciation is expressed to the following staff members of the Instructional Materials Laboratory for their efforts in producing this material: Phyllis Miller, Interim Director; Dan Stapleton, Assistant Director; Eileen Woody, Assistant Director; Veronica Feilner, Senior Editor; Kevin Gamble, Graphic Artist; Jan Trimble, Word Processor; and Jill Clark and Shelly Seabaugh, Editorial Assistants.

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FOREWORD

The development of the *Biotechnology: Applications in Agriculture* curriculum guide is the result of suggestions by the MVATA Teaching Aids Committee. The Biotechnology Advisory Committee suggested the topics to be included and reviewed the materials.

This student reference contains six units. Topics include an introduction to biotechnology, issues in biotechnology, basic laboratory skills, foundations of genetic engineering, animal technologies, and plant technologies. An instructor guide can be purchased separately.

During the summer of 1981, the Missouri State Board of Education formally adopted the concept of "Instructional Management Systems" (IMS) as a priority for the 1981-82 school year. The Missouri Commissioner of Education described the IMS concept as a practical way of "organizing for excellence" in education. To meet the demand for greater productivity and accountability, the director of Vocational Education applied the elements of IMS to form the Vocational Instructional Management System (VIMS). The VIMS process provides a framework to use in planning and organizing to assure excellence in Missouri's vocational education system by focusing greater attention on the management of teaching and learning.

The instructor guide to accompany this student reference incorporates the needed component parts to aid agriculture teachers in the implementation of VIMS.

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BIOTECHNOLOGY: APPLICATIONS IN AGRICULTURE

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Lesson 1:
An Overview of Biotechnology

The word "biotechnology" probably brings to mind an image of scientists in a laboratory, but it is much more than pure scientific research. Biotechnology is as old as making wine and as new as gene-splicing. It is applied to crops in the field and livestock in the barn.

Defining Biotechnology

The term "biotechnology" is often regarded as highly technical and scientific. Most members of the general public have heard of biotechnology, but they do not know how to define it. "Bio" refers to living things, and "technology" involves the application of science. Biotechnology can therefore be defined as the application of scientific principles to living things. It involves harnessing the natural biological processes of cells from microorganisms, animals, and plants to develop useful products. This broad definition of biotechnology includes processes such as fermentation and the use of yeast to cause bread to rise. These processes have been used for centuries.

A narrower definition of biotechnology includes only those processes that involve the recombination of genes from living things in a laboratory setting. The recombination of genes involves cutting and relinking a DNA strand. Modern biotechnology dates from the 1970s, when scientists first developed a way to splice genes from the DNA of one organism into the DNA of another organism.

When animals or plants reproduce sexually, DNA is transferred from the two parents to the offspring. This transfer of DNA is a natural process. Selective breeding of animals or plants can be considered biotechnology because a natural biological process is being harnessed to produce a useful product. Modern biotechnology, however, allows a scientist to transfer specific genes from one organism to another. The new organism will have a predetermined trait based on this genetic information.

The Past Role of Biotechnology

Biotechnology has played a vital role in crop production throughout history. One of the earliest examples of biotechnology was the development of fruit tree grafting techniques by the Greeks around 300 B.C. Crop biotechnology was greatly advanced by Gregor Mendel's experiments with garden peas in 1865 and his discovery of the foundations of genetics. The development of the first hybrid corn plant in 1879 is another example of how biotechnology has affected agriculture. In 1933, fewer than 1 percent of the U.S. corn crop came from hybrid plants, but by 1943, more than 70 percent of the crop was produced with hybrid corn. Crop production was again enhanced by the international development of improved wheat and rice varieties between 1946 and 1965.

Biotechnology has also been important in animal production. Selective breeding of livestock was practiced by people in the Middle East as early as 18,000 B.C. Animal crossbreeding and pure-breeding were practiced in Europe as early as 1500 A.D. A procedure for artificial insemination was first developed in Italy in the late eighteenth century.

Biotechnology has also affected the food processing industry. The use of bacteria to make cheese, bread, and alcohol began in Egypt between 4,000 and 2,000 B.C. The food processing industry was boosted by the invention of the modern distillery in the United States in 1830, which optimized the process of fermentation to produce alcohol. In the 1860s, Louis Pasteur discovered that fermentation was carried out by bacteria and confirmed the existence of microorganisms, leading to applications such as the large scale brewing of beer and wine.

Emerging Applications of Biotechnology

The modern era of biotechnology began with the first successful recombination of DNA in 1973. This achievement was the first step in the development of genetic engineering. Genetic engineering (also referred to as genetic modification or genetic manipulation) is the alteration of the genetic material of living cells by incorporating different genes to produce organisms with new characteristics.

In the late 1970s, scientists developed the technique of plant tissue culture. Tissue culturing has been important in the development of nearly all transgenic plants, or plants that incorporate genes from some other source. This process allows a plant breeder to grow an entire plant from only a few plant cells.

New technologies have been developed in animal biotechnology as well. After years of using artificial insemination, the livestock industry gained another

application of biotechnology with the development of embryo transfer techniques in the early 1980s. Methods of cloning animals have also been developed. In 1981, a Chinese scientist first cloned a fish. In Scotland in 1997, a ewe named Dolly was the first animal to be cloned from the cells of an adult mammal. Also in 1997, a calf named Gene was cloned from cells taken from a 30-day-old fetus.

The ability to alter DNA through genetic engineering has made many new products possible. The first genetically modified food product, an enzyme used in making cheese, was approved for use in the United States in 1990. Today, this enzyme is used to process most of the hard cheese produced in the United States. The first genetically modified crop plant was approved in the United States in 1994. This plant was the FlavrSavr™ tomato, which was engineered to taste better and have a longer shelf life. Insect-resistant and herbicide-tolerant crops were approved for use in the United States in 1995 and 1996. Animal vaccines produced from genetically modified bacteria were developed in the mid-1990s.

The future applications of biotechnology are not easy to predict. Several biotechnology products are currently being researched. Some of these products include environmentally tolerant crops and plants genetically modified to be used for biofuels. The future applications of biotechnology will address specific problems or obstacles preventing higher yields and higher quality agricultural products.

Consumer Perspectives toward Agricultural Biotechnology

Agricultural biotechnology is typically viewed by consumers as both positive and negative. Consumers in developed countries such as the United States like the idea of lower food costs, increased nutrient content, and having fresh fruits and vegetables available year-round. In developing countries, the interest is mainly in increased and cheaper food supplies.

However, some consumers in both developed and developing countries have concerns about the use of biotechnology. Some people fear that foods produced in this manner may not be safe to eat, even though U.S. regulatory agencies have stated that genetically modified foods are as safe as unmodified foods. Consumers also fear that agricultural biotechnology could harm or endanger the environment if genetically altered organisms are released.

The perspective of the consumer is an important factor in determining the market potential for products developed through biotechnology. Whether their fears are valid or not, consumers make the final decision about whether to purchase biotechnology products. Therefore, their concerns must be addressed.

Producer Perspectives toward Agricultural Biotechnology

Producers of agricultural products may also have both positive and negative feelings toward biotechnology. Producers see the potential for increased profits due to higher yields or lower input costs. Producers also see a benefit in reducing the amount of chemicals applied to their crops through the use of pest-resistant plants, since water supplies on their land would be better protected from contamination. Profitable new "customized" crops will benefit producers as well. Examples of customized crops are corn developed specifically for the production of ethanol or carrots developed for carrot stick snacks. Producers will receive premium prices for these types of crops.

Agricultural biotechnology does raise concerns among producers. Producers fear that small farms may not have the opportunity to use biotechnology and that large corporate farms may become more competitive and force them out of business. They also fear that a genetically modified crop could create a "super weed." The genetically modified plant could cross pollinate with a wild plant species to produce a plant that is nearly impossible to control. The debate continues as to whether there is any justification for these fears.

Nonagricultural Impacts of Biotechnology

Agriculture is only one of the areas affected by biotechnology. The human health industry, and particularly the producers of pharmaceuticals, have been greatly affected by biotechnology. Insulin for diabetics, for example, is now produced by genetically modified bacteria. It was the first product made by genetic engineering to be approved for sale in the United States. Many human vaccines have been developed using the same method, including a vaccine for rabies. Some human antibiotics and human growth hormones can be produced using modified bacteria. Biotechnology

has also affected the health industry through the development of tests that detect genetic disorders. Huntington's disease, Down's syndrome, Tay-Sachs disease, and cystic fibrosis can all be detected much earlier because of tests developed through biotechnology.

Another industry that is benefiting from biotechnology is the mining industry. Bacteria are being genetically modified for biomining. They will break down poor quality heavy metal ore. The metal can then be extracted much more easily. The bacteria will allow ore to be used that was once too costly to process.

Law enforcement and the criminal justice system have begun to use DNA for forensic purposes. A process called DNA fingerprinting can help to identify individuals who have committed a crime. It can also be used to match a child with its biological parents in cases where they have been separated due to war, kidnapping, or other circumstances.

The waste treatment industry and companies that clean up pollution are testing the use of genetically modified bacteria to treat sewage, clean up oil spills, and improve soil contaminated with organic compounds such as DDT. These bacteria literally feed on the undesired compound. Solid waste sites like landfills are examining the use of modified bacteria that will feed on the waste and give off methane gas, which can be burned as a fuel.

Summary

Biotechnology is the application of science to living things. Biotechnology has affected plant and animal production and the food processing industry, but it is also very important in many other areas, such as human health, mining, law enforcement, and waste disposal. Consumers and producers of recent products of agricultural biotechnology view them from different perspectives. These perspectives will influence the direction and pace of research in biotechnology in the future.

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Lesson 1:
Challenges to Biotechnology

Some people view biotechnology as an answer to problems like world hunger, but others see it as a source of social, economic, environmental, and ethical concerns. Critics of modern biotechnology express a fear that biotechnology may be advancing too rapidly, without adequate safeguards. This lesson will examine several issues surrounding modern biotechnology.

The Issues

Although many issues have emerged from recent scientific research in biotechnology, most of them can be categorized into one of five groups. The first group deals with the safety of consuming genetically engineered foods. Are there any negative effects from eating these foods? Is it possible that modified foods will trigger allergies? What are the long-term effects of a diet containing genetically modified foods? The second set of issues concerns consumer choice and the labeling of genetically modified foods. Should genetically engineered food products be labeled so that consumers who prefer not to eat them will know which ones to avoid? What are the problems associated with mandated labeling of foods? The third group of issues involves the safety of releasing genetically modified organisms into the environment. What are the consequences of allowing modified plants or animals to mix with closely related organisms? Is the release of these organisms reversible? The fourth group of issues involves questions about whether using biotechnology on animals to produce more meat, milk, or other products or to yield human health products jeopardizes the welfare of the animals. The fifth set of issues includes moral questions about whether genetic engineering of plants and animals is ethical.

Food Safety

The Food and Drug Administration (FDA) is the federal government agency in charge of making sure that the food supply is safe. The FDA states that genetically engineered foods are as safe as or safer than foods already on store shelves. The basis of their claim is that genetically modified foods must meet the same standards as other foods. Most of the research done on the safety of genetically engineered foods confirms that they are as safe as nonengineered foods. Many scientific studies show that modified crops do not differ in chemical composition from foods that have not been modified. The government, most researchers, and many consumers accept genetically modified crops as safe.

Questions persist about the safety of modified foods for humans, however. Some consumers, including some restaurants and chefs, have stated that they will not use any food that has been genetically engineered. They claim that the government has done very little to ensure the safety of these foods. Some scientists caution that since no long-term studies have been done on the effects of genetically modified foods on human health, no hard evidence exists on which to base statements about their safety over a long period. Some people who are concerned about food safety are calling for long-term testing to determine the effects of genetically engineered foods on humans.

Other consumers have more specific concerns about food safety. They fear that genes that cause allergic reactions may be introduced into a food that was previously safe to consume. They are also concerned that antibiotic-resistant genes (which are used during the process of genetic engineering) in modified food products may reduce the effectiveness of antibiotics used by people who consume the products.

Labeling of Genetically Modified Foods

Some people argue that genetically engineered foods should be labeled because the public has the right to know if a food has been modified. Individuals can then make an informed decision about whether to buy the product. Some people view genetic modifications as unacceptable for religious reasons. Vegetarians may want to avoid modified foods because they may contain genes taken from animals. Other people may simply wish to avoid eating genetically engineered foods.

The FDA has stated that since genetically engineered foods are no different from other foods, no need exists for labeling foods as modified. The FDA has two exceptions to this policy. The first is that if a gene that has the potential to cause an allergic reaction is placed in a food, the label must identify the allergen. The second exception is that if a significant change is made in the food's composition, a label must identify this change. A significant change in composition includes any

change in a food's nutrient or chemical content. The FDA states that it does not have the power to mandate that companies label foods to explain how they were developed.

Releasing Genetically Modified Organisms

Now that companies are marketing genetically modified crop seed such as insect-resistant cotton seed, the risk of releasing genetically modified organisms into the environment is again under debate. The governments of some countries, including the United States, Japan, and Australia, have stated that if nations follow voluntary precautionary policies, the environment is not at risk from modified plants and animals. The United States Department of Agriculture (USDA) had approved more than 25 genetically modified plants for commercial use by the end of 1996. Other governments, such as those in the Phillippines and many European nations, have refused to allow genetically modified crops to be imported or grown in their countries. They fear the release of genetically modified plants and animals into the environment. Unless these countries can work out their differences, international trade may be affected.

Some scientists say that releasing genetically modified organisms into the environment is dangerous because they may introduce altered genes into native populations, giving them undesired traits. For some plants, the risk of modified genes entering a wild population is nearly nonexistent; for example, no plants with which cotton can cross pollinate grow in the wild. However, the yellow crooked-neck squash, which has been modified to resist disease, can cross pollinate with a closely related weed, the Texas gourd. The modified plant is now nearing the marketing phase. The squash could possibly pass on the DNA that allows it to resist disease to this noxious weed. Weeds that do obtain the advantage of genetically modified traits could potentially choke out other plants.

Another concern some environmentalists have about releasing genetically modified organisms into the environment is their effect on biodiversity, or diversity in the numbers of different species of plants and animals. They fear that unmodified organisms will not be able to compete, which will eventually reduce the biodiversity that exists in nature. If this happens, not only would species become extinct, but a potential source of products useful to human beings could be lost. Important sources of genetic information would also disappear with the plants and animals that become extinct.

Animal Welfare Issues

As advances in animal biotechnology continue, questions will be raised about whether the genetic engineering of animals is ethical from the standpoint of animal welfare. Some people question whether it is morally right to genetically engineer an animal to alter its natural ability to produce. One concern is that increasing an animal's production capacity may cause poorer animal health. When the FDA approved bovine somatotropin (BST) in 1994, controversy arose over whether the 10 to 20 percent increase in milk production was desirable, since a higher rate of mastitis and a change in the composition of milk might also occur. Studies of BST done in the United States have shown few effects on animal health. However, European countries, under the pressure of animal rights groups, still do not allow the use of BST.

Some people argue that genetically engineering livestock to produce pharmaceuticals and other health products for humans is inhumane. Some animals have already been genetically engineered to produce a desired pharmaceutical in their milk. Pigs that have been modified to produce human blood plasma must be killed to harvest the product. Opponents believe that such uses of animals are unethical.

The Morality of Genetic Engineering

Some groups have raised the basic question of the morality of genetic engineering as a whole. People who hold this viewpoint commonly express one of two main moral objections. The first is that humans are "playing God" by manipulating the basic elements of life. Doing so oversteps the bounds of what is appropriate for humans. Counter arguments generally state that human beings should use all the knowledge available to them to improve the human condition. The second moral objection is that genetic manipulation will permanently alter the balance of nature. This view states that human beings should not interfere with natural processes but should learn to live in harmony with their environment. The opposing argument is that humans have manipulated nature in many ways throughout history, and biotechnology is just another way to do so.

Summary

Many social and moral issues are associated with biotechnology. These issues include the safety and labeling of genetically modified foods, the safety of releasing genetically modified organisms into the environment, animal welfare issues, and the morality of genetic engineering itself. These issues are being debated in public forums. Coming up with acceptable answers for these tough questions will take time, but many people consider the debate to be healthy and important in shedding light on these issues.

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Lesson 2:
Agencies Involved in Biotechnology

In addition to raising new ethical concerns, advances in biotechnology are posing new regulatory questions. Various government agencies are involved in overseeing biotechnology. In 1986, a "Coordinated Framework" was developed to specify which agency has the authority to regulate specific biotechnology research programs or products. The role of each of the federal agencies involved in regulating biotechnology will be briefly described and explained in this lesson.

The Environmental Protection Agency (EPA)

The Environmental Protection Agency (EPA) has the broad responsibility of regulating all chemical substances being used as pesticides. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and the Toxic Substances Control Act (TSCA), which were enacted by Congress before genetic engineering was discovered, gave the EPA this responsibility. The federal government and the EPA have concluded that any pesticidal quality of a plant is a form of a pesticide and as such is regulated by the EPA. The EPA is therefore involved in overseeing the development and testing of plants genetically modified to protect themselves against pests. In 1995, the EPA approved more genetically engineered pesticide products than traditional chemical pesticides.

The EPA must review and approve applications for plants that are modified to resist pests before they can be field tested. The agency must issue an experimental use permit before approving a field test for a genetically modified plant. The application for the permit requires the submitting party to document the genetic makeup of the organisms from which the new organism was developed, as well as the genetic identity of the new organism itself. This information is often provided through the use of DNA fingerprinting. In addition, the applicant must submit a detailed plan for monitoring and conducting the proposed field test. Results from laboratory tests must be included in the application as well.

Not only must the genetically modified plants be approved, but the EPA must also approve the use of pesticides on the new plant. For example, the EPA would need to approve the chemical Roundup™ made by Monsanto for use with Roundup-tolerant soybeans. EPA approval allows the company to label the product for use on these soybeans.

Because the government has defined all genetically modified microorganisms as "new chemical substances," these organisms are also under the authority of the EPA. Modified organisms include fungi, bacteria, viruses, and protozoa. The EPA must review and approve each of these new "chemical products" before they can be manufactured for commercial use. To help ensure environmental safety, the approval process is complex, because microorganisms are impossible to control once they have been released.

The United States Department of Agriculture (USDA)

The U.S. Department of Agriculture (USDA) is involved in agricultural biotechnology in several capacities. The USDA promotes advances in biotechnology by funding a great deal of research in biotechnology. The USDA is also responsible for regulating agricultural research and products.

The Animal and Plant Health Inspection Service (APHIS) is an agency of the USDA that is primarily responsible for managing and enforcing all biotechnology-related regulations from the USDA. APHIS has two major functions in regulating biotechnology. They require that prior approval be given in the form of a permit for the field testing, shipping, and delivery of any seed or plant modified through biotechnology. This requirement was suspended in 1993 for six crops that have a history of safe genetic modification. These crops include genetically modified corn, soybeans, cotton, potatoes, tobacco, and tomatoes. APHIS only requires notification 30 days prior to field testing for these crops. The second major function of APHIS is reviewing how research was conducted and its results. This review outlines possible concerns posed by the release of the new crop or product for the researcher requesting the field test. These concerns must be addressed before the field test can take place.

The Food and Drug Administration (FDA)

The Food and Drug Administration (FDA) is the federal agency responsible for ensuring the safety of the nation's food supply. The FDA published a policy statement in May of 1992 that has become the basis of its regulatory policy concerning plant

biotechnology. This policy states that the FDA will regulate genetically modified food products or food additives in the same way as food products or food additives produced by other methods. Only the characteristics of the food, not the method of development, are important to the FDA.

The FDA generally allows foods to be introduced to the commercial market with the stipulation that the party introducing the food notify the administration of its planned introduction. The FDA has the power to remove a food from the market at any time if it determines that a "reasonable possibility" exists that the food is unsafe for public consumption. Many new foods, including genetically modified foods, are therefore not required to have prior approval but could be withheld from the market if the FDA suspects that they are unsafe. The responsibility of proving that a new food is safe rests fully on the manufacturer of that food.

Some genetically modified foods, however, must receive approval from the FDA before they are marketed. According to the 1992 policy statement, if a new food contains a substance known to cause allergic reactions, or if introducing or removing a substance causes the product's nutritional value to change, then prior approval is necessary. A food that contains genetic material from a source not currently in the food supply must also be approved prior to marketing. In most cases, this approval requires that the food product be labeled to indicate that a known allergen is present, that the nutritional value of the food has changed, or that a toxin is present in the food.

The FDA also regulates all drugs and drug delivery systems sold in the United States. Genetically engineered animal vaccines must therefore receive FDA approval. The average length of time needed to obtain FDA approval for a new drug is nine years.

The Occupational Safety and Health Administration (OSHA)

The mission of the Occupational Safety and Health Administration (OSHA) is "to save lives, prevent injuries, and protect the health of American workers." OSHA is a division of the United States Department of Labor that was created by the Occupational Safety and Health Act of 1970. Nearly 100 million workers and their 6.5 million employers are under the supervision of OSHA. OSHA is involved in agricultural biotechnology primarily to ensure that workers in biotechnology work in a safe environment. Lighting, ventilation, possible exposure to dangerous chemicals or microorganisms, and the presence of safety equipment are all things that OSHA looks at when inspecting a facility.

The National Institutes of Health (NIH)

The National Institutes of Health (NIH) is a federally funded agency with a mission "to uncover new knowledge that will lead to better health for everyone." NIH is involved in biotechnology in many ways. For example, NIH conducts research in biotechnology in its own laboratories and financially supports the research of nonfederal scientists in various public and private institutions within and outside of the United States. It also regulates the research that it funds. NIH aids in the training of research scientists by funding graduate student research efforts. It helps foster biomedical communication by linking scientists through newsletters, conferences, and professional publications.

In July of 1994, NIH published a newly revised set of guidelines for research involving genetic modifications. This set of guidelines is very technical and comprehensive. They range from facility requirements for safe containment of microorganisms to explanations of which specific activities require prior NIH approval. NIH does not regulate any field trials of genetically modified organisms but refers researchers to the USDA and other federal agencies. The agency has no control over research that it does not fund. However, many researchers in both public and private institutions voluntarily follow NIH guidelines.

The Nuclear Regulatory Commission (NRC)

The Nuclear Regulatory Commission (NRC) is an independent agency established by Congress under the Energy Reorganizational Act of 1974. Although the primary function of the NRC is the regulation of nuclear reactors and nuclear facilities, it also regulates the possession, use, processing, handling, and export of all radioactive material. Most academic and industrial biotechnology research laboratories use very small amounts of radioactive materials to conduct certain experiments. They must work with the NRC to obtain, use, and dispose of radioactive substances. The NRC must issue a special permit for anyone transporting, handling, storing, or disposing of radioactive materials.

Regulating International Trade

All of the above agencies regulate biotechnology in some manner in the United States. However, biotechnology is an international industry and as such must abide by each country's regulatory systems. A movement exists to establish a legally binding international protocol that would set standards by which individual countries could evaluate the possible risks involved with the use of genetically modified organisms. International cooperation in regulating biotechnology is important since food products are frequently imported and exported. International committees are meeting to try to establish voluntary guidelines for the movement of genetically modified organisms between nations.

Summary

Several federal agencies oversee the biotechnology industry in the United States. The EPA, USDA, and FDA all have important roles in monitoring biotechnology. These federal agencies work together to ensure that new biotechnology products are safe to use. Other agencies and associations, like OSHA, NIH, and the NRC, play a smaller but vital role. International treaties and agreements could also affect certain aspects of biotechnology. The way biotechnology is regulated may need to change as the science of biotechnology changes.

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Lesson 3: Biotechnology Patents

The biotechnology industry would not be as advanced as it is today if it were not for the ability to patent biotechnology products. While the decision to allow patents for genetically modified plants and animals is controversial, it has stimulated research in genetic engineering in the private sector. Patent applications are made as soon as a discovery or development that promises to have a useful application is verified. The research is kept secret until the patent is granted. This lesson will examine patents for products of biotechnology and the issues surrounding the patent process.

U.S. Patents

In the United States, patents are issued by the U.S. Patent and Trademark Office (USPTO). A patent issued by the USPTO grants the holder property rights that exclude others from making, using, or selling the patented invention throughout the United States for a stated period. Normally, this period is 17 years. In exchange for this exclusive right, the public receives the details of the "invention." The purpose of this disclosure is to allow others the ability to develop and market the product after the patent expires. It also stimulates further research by competitors to develop new inventions that are related to, but not covered by, the patent.

The USPTO grants three types of patents. The most common type of patent is the utility patent. The utility patent is granted for inventions that are "new and useful" and that meet certain statutory requirements. The second type of patent is the plant patent. The Plant Patent Act of 1930 permits patent protection for particular types of plants. This patent is issued to anyone who invents or discovers and asexually reproduces any new variety of plant. The new plant variety may consist of cultivated spores, mutants, hybrids, and newly found seedlings. The applicant must be able to prove that the plant is different from other plants to receive the patent. The third type of patent is the design patent, which is issued for a new, original, and ornamental design for a manufactured article. Biotechnology products are not eligible to receive a design patent.

Patent Requirements

Many biotechnology products have obtained U.S. patents. For example, the first animal patent was issued in 1988 for a transgenic mouse developed from a fertilized mouse egg cell that had been genetically modified, establishing that modified animals can be patented in the United States under the current patent laws. Other biotechnology products that have been patented include genetically altered microorganisms, seeds, tissue cultures, and altered or nonnatural forms of a molecule, such as a modified protein molecule.

Since most biotechnology products receive a utility patent, an understanding of the requirements of this patent is important. A utility patent has three basic statutory requirements. The first is that the invention must be a new and useful process, machine, manufactured item, or composition of matter. Most biotechnology products fall into the "composition of matter" category since they are essentially rearrangements of DNA. The second statutory requirement is that the invention must be novel and nonobvious. An invention is obvious if it can be readily deduced from information available to the public by a person knowledgeable in the relevant technological field. The final statutory requirement is that the invention must be fully described and clearly claimed in the patent application.

Products must meet the definition of a patentable invention. Laws of nature, physical phenomena, and abstract ideas are not patentable; no one can patent gravity or centrifugal force, for example. For a patent to be granted, other qualifications must be met. A patent cannot remove anything from the public domain. This requirement means that something already commonly used cannot be patented. Not only must the patent not remove anything from the public domain, but it must add adequate information about the invention to the public domain. This information is disclosed as a part of the patent application.

Issues Surrounding the Patenting of Biotechnology Products

One of the issues surrounding biotechnology patents is the question of ownership of the genetically modified organism. Should genetically modified plants and animals be deemed the property of the individual or corporation responsible for modifying them? The answer to this question is controversial. Some people view genetic material

as being owned by everyone and therefore nonpatentable. Those people who believe in the universal ownership of genetic material contend that genetic modifications are not patentable as inventions. However, others disagree, pointing out that genetic modifications constitute a rearrangement of matter. So far the USPTO and the U.S. Supreme Court have confirmed the patentability of genetically modified organisms. Much debate still exists on how broad the patents may be.

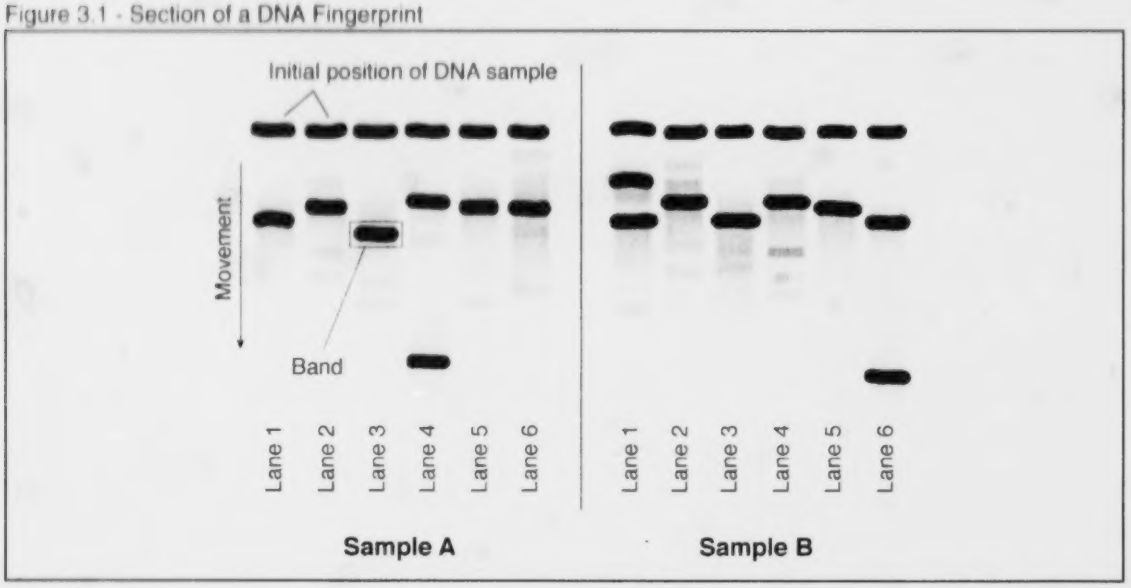
Other controversies surround the patenting of the genetic material of plants and animals native to countries other than the United States. Does a country own the DNA of native plants and animals? Should the United States grant patents on plants that have been used for centuries in Third World countries? A patent of this type was granted to a U.S. corporation for the genes producing the insecticidal properties of the seeds of neem trees. Farmers in India have used neem tree seeds as an insecticide for centuries. Even though the patent only covers the use of the insecticidal properties of neem seed in the United States, India would have to honor the patent due to international trade treaties. This patent has sparked an international lawsuit and much international debate.

DNA Fingerprinting

Fingerprints have been used for decades by the criminal justice system to link individuals to evidence and to identify persons involved in crimes. More recently, DNA fingerprints have been used in the same way. DNA fingerprinting is the process of using laboratory analysis of DNA to generate a pattern that is unique to an individual organism. DNA fingerprinting is useful any time the exact identity of an organism must be confirmed. For example, the patent process requires that genetically modified organisms be conclusively identified, and DNA fingerprinting can provide this information. It is also used for insurance applications that require proof of the exact identity of a plant or animal and for breed associations that need to record the exact identity of an animal.

DNA fingerprinting is a complicated process involving several steps. The first step is to isolate DNA from an organism. The DNA is cut into many specifically sized pieces using an enzyme in a process called restriction digestion. After a probe dye is added to the DNA, it is sorted by the length of the pieces through a procedure known as gel electrophoresis, in which the pieces are placed in a gel and move through it along paths called lanes when an electric current is applied. Some of the pieces are "tagged" by the dye, which is a marker that attaches to a specific location on the DNA. The result is a pattern that looks like a set of bands (Figure 3.1) that identify the organism from which the DNA was extracted.

Figure 3.1 - Section of a DNA Fingerprint



Problems with Handling Genetic Material

A major problem associated with the ownership of any genetic material through a patent is that in theory only a small amount of tissue, blood, or even hair is needed from a plant or animal to make a copy of the plant or animal. The owners are therefore vulnerable to the theft of the genetic material by those handling it. For example, ranchers who want to maximize the productivity of a certain animal may choose to use embryo transfer. If a dishonest veterinarian or technician is hired to perform the procedure, he or she could keep and sell some of the embryos collected.

Other problems associated with handling genetic material are the consequences of flawed test results and the ability to preserve the privacy of genetic information. Flawed results in genetic testing caused by mislabeled samples or experimental error could lead to disastrous decisions about ownership. Breed registrations may be denied or insurance policies made invalid due to flawed DNA fingerprinting results. The privacy of genetic information is also an issue. Controlling access to the genetic information of people, and to a lesser extent animals and plants, is a challenge facing the biotechnology industry.

Summary

Products of genetic modification can be patented in the United States if they meet certain requirements. Issues surrounding the patenting of biotechnology products will probably to be debated for many years. However, genetically modified plants, animals, and microorganisms will likely continue to be patented.

Credits

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Lesson 1:
The Scientific Method

Agricultural biotechnology is a rapidly expanding area of research. This growth makes the documentation of research methods, procedures, and results vitally important. With so many researchers exploring the applications of agricultural biotechnology, proper research methods and proper documentation of those methods is necessary. The scientific method helps researchers organize their experiments and allows other researchers to duplicate their work, which adds credibility to the results. Patent applications have been rejected or slowed due to poor documentation of research or poor research methods, both of which make replicating the research difficult. This lesson will outline the proper method of designing biotechnology research efforts.

The Scientific Method

The scientific method is a way of addressing scientific questions that provides a rational and structured system for research. A single biotechnology research effort may cost hundreds of thousands of dollars or more. A solid research approach is necessary to ensure the wise use of funds. Biotechnology researchers use the time-tested structure of the scientific method when conducting research.

The scientific method used by biotechnology researchers has six major parts. The first step in using the scientific method is to identify the problem to be investigated in a problem statement. The problem statement expresses the general purpose of the research. Knowledge about the problem or question for which an answer is being sought is required. The problem must be stated in such a way that it will lead to experimentation that will solve the problem. A sample problem statement is "Some plants in a corn field have yellow leaves."

After the problem has been identified, the second step is an investigation into previous research to identify alternate explanations or solutions to the problem. This activity leads into the third step of the scientific method, which involves formulating a hypothesis, or educated guess, about the anticipated outcome of the research. The hypothesis is essential, since experiments are developed to validate or invalidate this statement. It must be a focused and detailed statement that can be tested for accuracy. A hypothesis for the problem statement in the preceding paragraph is "Nitrogen deficiency causes the corn plants' leaves to be yellow." Since the hypothesis will direct the methods of experimentation, the hypothesis is the most important statement made by the researcher.

The fourth step is to design an experiment that will accurately test the hypothesis. This step is also a critical step. If the hypothesis is correct but poor experimental methods are used to test it, the chance of obtaining usable results is reduced. Selecting experimental methods for research requires knowledge of the available testing procedures and their advantages and limitations.

The fifth step of the scientific method is to conduct the experiment and collect data. When experimentation is complete, the final step is to draw conclusions about the success of the experiment by analyzing the information it provides. Based on this information, the researchers will accept or reject the hypothesis. The results of the experiments are examined, and evidence about answers to the original problem is detailed. As a part of this step, the limitations of the research results must also be explained. The conclusions collected must be supported by evidence in order to be valid.

Many researchers must add an additional step to this process. After the experiments have been chosen to test the hypothesis, researchers generally have to write a proposal. This proposal is directed at one or more funding agencies that provide funding to support research efforts. Researchers who work for private companies do not normally write a formal proposal, but they must still convince the company that the proposed research is worthwhile.

Importance of the Scientific Method

A logical question to ask when discussing the scientific method is simply, "Why is the scientific method important for research?" Three main reasons for its importance exist. First, the scientific method provides a logical approach to solving a problem. Scientific research, including research in biotechnology, is essentially a search for the unknown. The search for an unknown requires a basic, comprehensive search beginning from a given point. The scientific method helps researchers to analyze the known information and to select the best way to find the desired answers. Second, the

scientific method is important because it helps force researchers to examine their research objectively. The structure of the scientific method aids in identifying alternative answers to research questions since the researchers must carefully examine existing research in the area of interest. A final reason that the scientific method is important is that its use allows other researchers to repeat the experiments. Other researchers need to be able to duplicate the results of an experiment before its validity can be fully established. Research that follows the scientific method is more easily understood than research that does not follow that structure. Research must follow the scientific method to gain professional credibility.

Laboratory Notebooks

Laboratory notebooks serve an important function in biotechnology research. Notebooks provide a detailed account of the day-to-day activities of the experimental process. These notes are vital in examining directions for future research and for proving that specific research was done at a set time, which is required for patent applications. When research is not successful, researchers often review laboratory notebooks so that new research efforts can better address the problem. A notebook should be bound and written using permanent ink. It should also be complete, covering actual activities and all observations made. The laboratory notebook should have a cover that identifies the subject of the research and a table of contents.

Information from individual experiments is recorded on laboratory sheets. These sheets contain six major sections. The first section is for the title of the experiment, the date, and the name(s) of the investigator(s). The second section should briefly describe the purpose of the experiment. A list of materials needed should be included next. The procedures for the experiment should be outlined in the fourth section. These procedures should be detailed and include specific quantities of substances used, as well as the precise methods of using them. The next section should be a record of experimental results in the form of data and observations. Finally, the conclusions drawn from the research are recorded at the end of the laboratory sheet.

Summary

The scientific method is an important tool in research for biotechnology. Without the logical structure of the scientific method, research would involve a blind search for answers. The six parts of the scientific method help researchers organize their research efforts and increase the likelihood of success. The laboratory notebook is an important source of documentation for researchers. This notebook should be a complete, day-to-day account of the research.

Credits

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Lesson 2:
Laboratory Equipment and Techniques

The heart of biotechnology is the research laboratory. Biotechnology laboratories are equipped with many types of tools and instruments. Individuals involved in biotechnology should be familiar with the equipment used in these laboratories as well as special procedures for developing and maintaining suitable working conditions that are free of contaminants.

Laboratory Equipment

Laboratories where biotechnology research is conducted contain many different types of laboratory equipment. The specific equipment found in a given laboratory will vary based on the type of research being done. However, most laboratories have a basic set of equipment.

The pipettor (Figure 2.1), which is used to measure and transfer amounts of liquid smaller than one milliliter (ml), is a common tool in biotechnology laboratories. Pipettors are available in three main sizes: zero to 20 microliters (µl), 20 to 200 µl, and 200 to 1,000 µl.

A variety of plastic ware and glassware is used in the biotechnology laboratory. Pipette tips, test tubes, and centrifuge tubes are examples of plastic ware used in a laboratory. Petri dishes made of plastic or glass are the containers most commonly used for growing bacteria or tissue cultures. Glassware used in laboratories includes beakers, flasks, graduated cylinders, and test tubes. Figure 2.2 shows some examples of plastic ware and glassware.

Figure 2.1 - Pipettor

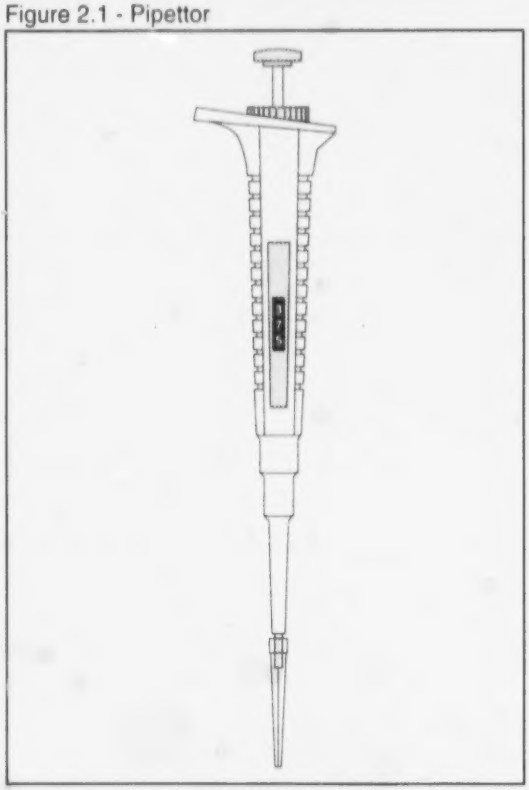
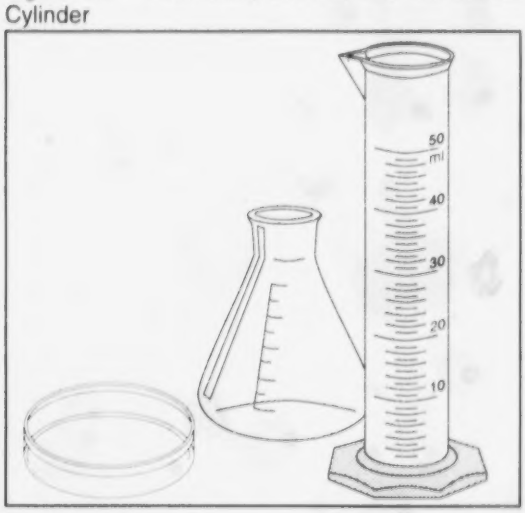


Figure 2.2 - Petri Dish, Beaker, and Graduated Cylinder



Researchers sterilize most of the plastic ware and glassware in an autoclave, which is illustrated in Figure 2.3. An autoclave uses steam under high pressure for sterilization.

Figure 2.3- Autoclave

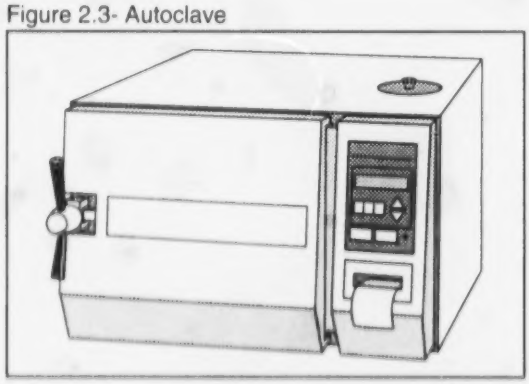
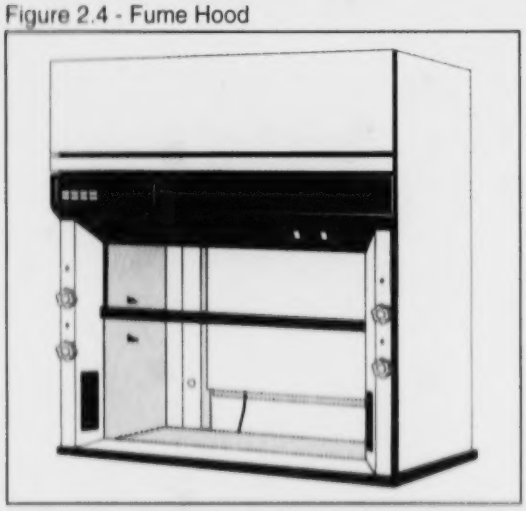


Figure 2.4 - Fume Hood

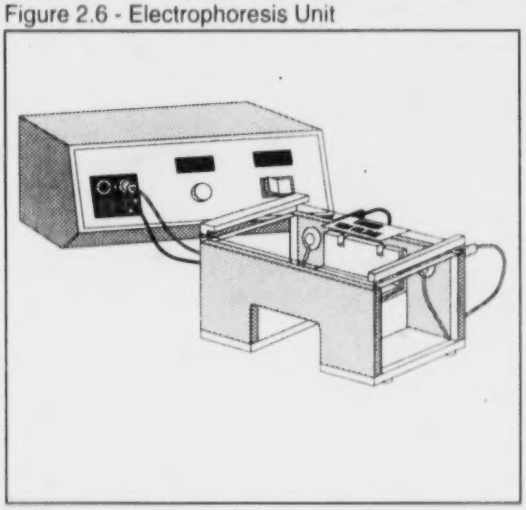


A fume hood (Figure 2.4) is an enclosure that vents air to the outside. Fume hoods allow researchers to use chemicals with dangerous or noxious fumes. They are commonly sterilized with ultraviolet light or a 70 percent alcohol solution when researchers do tissue culture and other sensitive procedures.

Another piece of equipment needed for tissue culture and the propagation of bacteria is an incubator, which is shown in Figure 2.5. An incubator maintains a preset temperature that provides an optimum climate for cell cultures to grow.

An electrophoresis unit (Figure 2.6) is a common piece of equipment. Electrophoresis separates DNA fragments by size using an electric current. The electrophoresis unit is like a sieve for separating these microscopic fragments. The fragments are shown on an electrophoresis gel.

Figure 2.6 - Electrophoresis Unit



A transilluminator, shown in Figure 2.7, is used to view an electrophoresis gel. A transilluminator illuminates the gel by passing a shortwave ultraviolet light through it. Regular light will not show the dyes used to stain the gel.

Polymerase chain reaction (PCR) equipment is also found in biotechnology laboratories. PCR is a method of increasing the quantity of DNA in a sample by heating and cooling the DNA to break it down and force it to replicate. PCR equipment

Figure 2.5 - Incubator

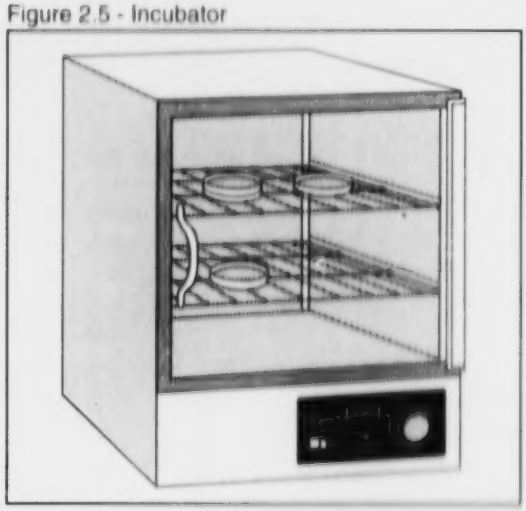


Figure 2.7 - Transilluminator

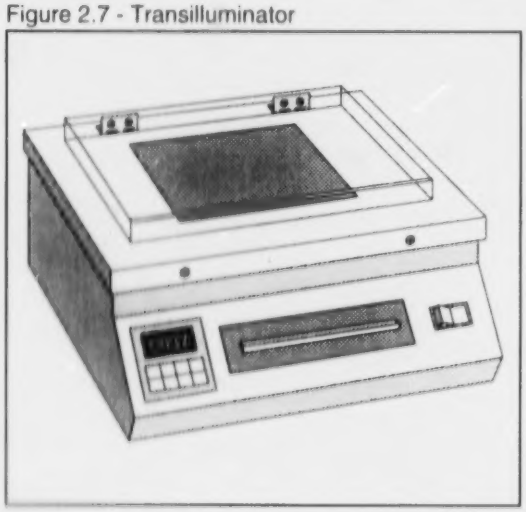
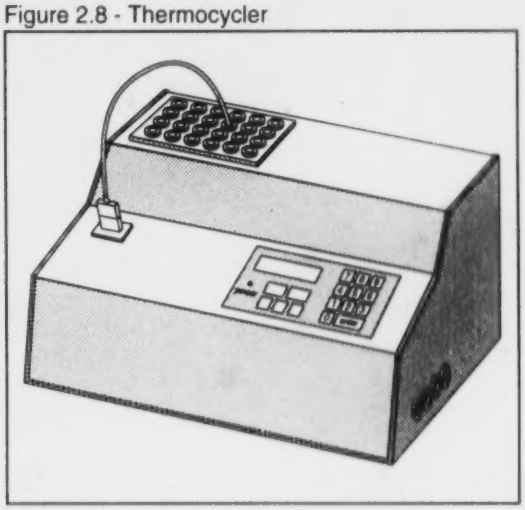


Figure 2.8 - Thermocycler

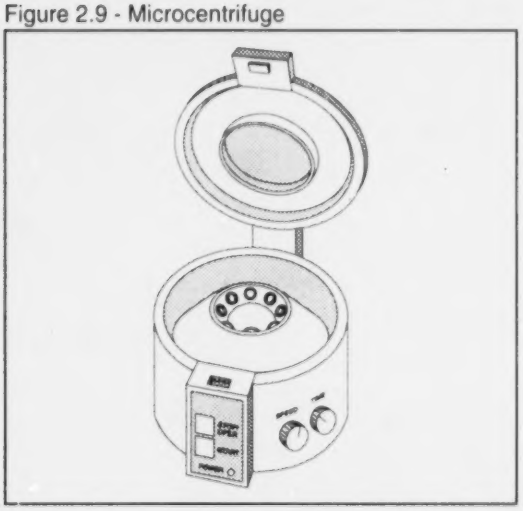


takes various forms, from a series of water baths to the newest automated form, the thermocycler (Figure 2.8).

DNA is separated from a liquid by using a microcentrifuge, which is illustrated in Figure 2.9. A microcentrifuge is essentially a high power spinner that uses centrifugal force to separate solids, such as DNA, from a liquid.

A vortex is a vibrating mixer used on test tubes. It mixes a solid or liquid with a liquid. A test tube is placed on a small rubber cap that vibrates in a circular motion, which causes the contents of the test tube to mix.

Figure 2.9 - Microcentrifuge



The microscope is an important device for enlarging and viewing organisms or specimens that are not visible to the naked eye. Two basic types of microscopes are used in biotechnology laboratories. The dissecting microscope is a low-power microscope that magnifies 10 to 100 times. This microscope is used in embryo transfer and tissue culture techniques. The second type of microscope is a general laboratory microscope that magnifies 100 to 1,000 times.

The Microscope

A microscope (Figure 2.10) has many parts. The ocular, or eyepiece, is the initial point for viewing a specimen and contains the first lens system, which normally magnifies the specimen 10 times (10X). The second lens system is called the objective. It projects the magnified image up through the ocular. Most microscopes have two or three objectives that vary in their degree of magnification. A rotating piece called the nosepiece holds the objectives.

The body tube of the microscope holds the ocular and the objectives the correct distance apart. The arm is the curved support that connects the body tube to the base. The base is the stand on which the microscope rests. Slides containing the specimens to be observed are placed on the stage, which has clips to hold the slide in place.

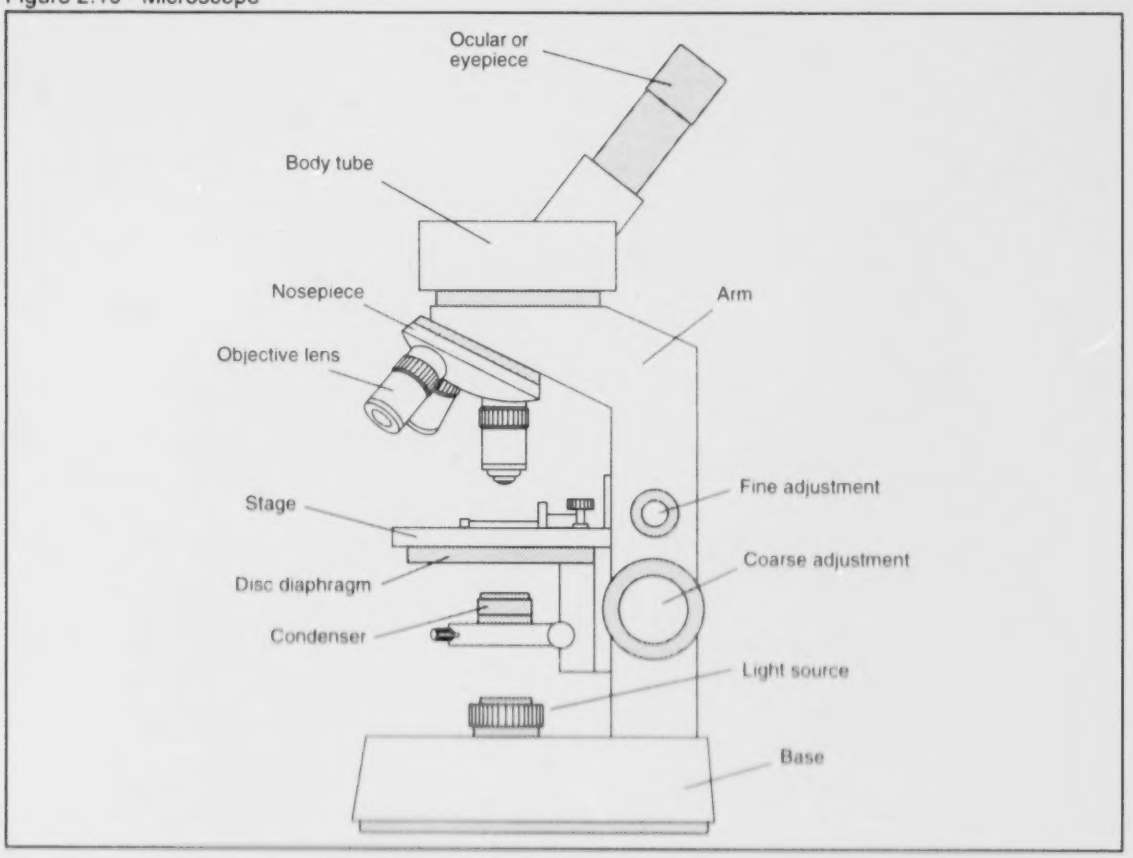
The disc diaphragm contains a series of different sized openings that control the amount of light shining on the specimen. The light comes from a light source like a mirror or small electric lamp. On microscopes with a lamp, a condenser focuses the light on the specimen.

The two main dials for adjusting a microscope are the coarse adjustment and the fine adjustment. The coarse adjustment is the larger of the two dials; it is always used first to focus on a specimen with the low power objective. The fine adjustment refines the focus. With the high-power objective, only the fine adjustment is used to focus the microscope.

Procedures for Manipulating Microscopic Specimens

A specimen viewed under a microscope must be very thin since it is placed, or mounted, on a glass slide. If a wet mount is needed, a drop of water should be added to the specimen. Usually, a cover slip is placed on top of the specimen; gently pressing on the cover slip will remove air bubbles.

Figure 2.10 - Microscope



To view some specimens correctly, they must be stained. The correct staining procedures vary greatly from specimen to specimen.

Once the slide is prepared, it is placed on the stage and secured by the clips. Next, the light source must be turned on and adjusted so that light passes through the specimen. The low-power objective is then selected, and the coarse adjustment is used to focus the specimen's image. If more magnification is needed, the high-power objective is selected, and the fine adjustment is used to focus the image. The fine adjustment should only be used to move the objective up and away from the stage. If either the coarse adjustment is used or the fine adjustment is adjusted toward the specimen slide while using the high-power objective, damage to the objective can result.

Aseptic Techniques

Aseptic techniques are procedures used to create and maintain a work area free of bacteria and other microorganisms that might contaminate delicate experiments. A sterile environment is necessary for procedures such as tissue culture or the propagation of bacteria. Some aseptic techniques are described below.

- *Controlled air movement* - The researcher works in an enclosed chamber that allows the flow of air to be controlled.
- *Disinfection* - The work area is disinfected with a 10 percent bleach solution. Then the instruments and work area are sprayed with a 70 percent ethanol solution and allowed to air dry.
- *Scrubbing up* - The researcher scrubs his or her hands and arms thoroughly and allows them to

air dry. He or she then sprays them with a 70 percent ethanol solution.

- *Sterilization* - Researchers use an autoclave to sterilize all materials and instruments. An ultraviolet light kills microorganisms in the work area.

A researcher may maintain an aseptic work area by using a shield to avoid breathing on an experiment. He or she should also avoid sneezing or coughing in the work area. When using a fume hood, researchers should use the rear portion of the enclosed area to reduce exposure to bacteria that might enter the area.

Importance of Aseptic Techniques

Experimental procedures like tissue culture and most DNA analysis techniques require proper aseptic techniques to be successful. Contaminants will destroy many biotechnology experiments, so the work environment must be free of them. Bacteria, viruses, and other microbes can interfere with many laboratory procedures.

Summary

Many different types of laboratory equipment are used in biotechnology research. A basic piece of equipment is the microscope, so understanding its parts and their functions is important. Researchers must also know the procedures for manipulating microscopic specimens. Researchers in biotechnology should practice aseptic techniques to prevent the contamination of their work.

Credits

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Lesson 3:
Biotechnology Laboratory Safety

Biotechnology researchers use many types of equipment, chemicals, and specimens in their work; the correct use of all three is vital to the safety of the researchers. Laboratory safety is a very high priority in biotechnology laboratories. The ability to handle chemicals and specimens safely and to use equipment correctly is necessary for employment. A knowledge of emergency procedures for chemical spills and fires is also critical. This lesson highlights some of the most important safety precautions and concerns.

Common Biotechnology Laboratory Safety Concerns

Common biotechnology laboratory safety concerns fall into five major categories: microorganisms, chemicals, radioactivity, electrical hazards, and physical hazards. The use of bacteria and fungi is common in biotechnology laboratories. Some microbes, called pathogenic microbes, are dangerous because they are capable of causing disease. These types of microbes require special containment laboratories and are not used in school laboratories. However, all microorganisms should be handled properly, since even nonpathogenic microorganisms can be harmful in certain cases. Care should be taken to follow aseptic techniques strictly in order to contain microorganisms.

Many types of chemicals are used in biotechnology laboratories, including solvents, enzymes, dyes, and buffers. These chemicals are safe if handled correctly. Care must be taken to avoid contact with the skin. Many chemicals can be absorbed through the skin or spread onto other surfaces by contact. Most of the dyes and buffers are toxic if ingested. Use of these chemicals should be limited if a suitable alternative is available.

Radioactivity is used in biotechnology laboratories for probes or markers that verify the transfer of DNA segments. A special permit is required to use radioactive materials. To obtain a permit, researchers must complete training about the safe handling and disposal of radioactive substances. Radioactive materials are not used in school laboratory settings.

Electrophoresis equipment can be an electrical hazard. This equipment is safe if used properly. However, if safety precautions are not observed, electrical shock can occur. An individual should never touch the gel solution while the machine is on.

Centrifuges and ultraviolet lamps used in biotechnology laboratories are considered physical hazards. A centrifuge should have a lock that prevents the lid from opening while the machine is spinning. This safety feature prevents fingers from being caught in the rotating machine, which can cause serious injuries. With prolonged exposure, ultraviolet radiation from a transilluminator can damage retinas and bare skin.

Cleaning Up Spills

The possibility of a spill exists whenever chemicals are handled. When the spilled chemical is known, clean up procedures for that specific chemical should be used. The proper procedures are outlined on a Material Safety Data Sheet (MSDS). Chemical suppliers develop these sheets and ship them with all chemicals. The sheets must be kept in a specific notebook or file for easy reference. The MSDS provides a variety of information about the chemical, including its toxicity level, first aid measures, required personal protective equipment, and disposal procedures.

When specific clean up procedures are not available or the content of the spill is unknown, special procedures must be followed. A spill pillow (Figure 3.1) is used to absorb any liquid chemical. The used spill pillow should be regarded as hazardous waste and disposed of appropriately. If the spill is a solid or a powder, it can be gently swept into a glass container and disposed of as hazardous waste. The spill area should be cleaned with a disinfectant and an ethanol solution to ensure that any remaining traces of the chemical are removed.

Figure 3.1 - Spill Pillow

Disposal of Biotechnology Laboratory Waste

Biotechnology laboratories commonly produce waste products classified as hazardous waste, which must be disposed of appropriately. Simply dumping everything down the drain is not acceptable. Some of the waste generated by a biotechnology laboratory can be decontaminated and thrown away with other trash to be placed in a landfill. All cultures and equipment that have come in contact with infectious microbes must be autoclaved or disinfected with hospital-type disinfectants before being thrown away. Examples of chemicals requiring special disposal are organic solvents and highly toxic chemicals. The proper disposal method for a chemical substance is found on the chemical's MSDS. Improper disposal of hazardous waste endangers the environment, and a company may receive large fines if OSHA or the EPA discovers that proper disposal procedures are not being followed.

Emergency Fire Procedures

Biotechnology laboratories, like all laboratories, must be prepared for emergencies. A fire exit plan should be posted in the laboratory. In a research laboratory, just as in a classroom laboratory, the fire exit plan should be followed if a fire breaks out and should be practiced during fire drills. Everyone should know the location of the fire extinguisher, the fire blanket, and the fire alarm switch. If a fire occurs in a classroom lab, students should immediately notify the instructor and begin exiting the room.

Personal Protective Equipment

Personal protective equipment (PPE) can help prevent injury to laboratory workers. All laboratories require workers to wear safety glasses or goggles while in the laboratory. They also require latex or other appropriate types of gloves for most laboratory work. Normally, workers use disposable latex gloves. Lab coats or aprons should be worn to protect clothing. Shorts, short skirts, and sandals are not permitted because they expose too much skin to the laboratory environment.

Injuries in the Laboratory

Anyone working in a laboratory should know what to do if an injury occurs. Simple first aid procedures, like applying pressure to stop blood loss or flushing skin or eyes with water if they come in contact with chemicals, should be done immediately. In a classroom lab, the instructor should also be notified without delay so that he or she can follow the school procedure for emergencies. Students should always read and follow any precautions noted in a laboratory exercise to help avoid injury.

Laboratory Ventilation

Most biotechnology laboratories do not require special ventilation. A fume hood vented to the outside is necessary when using chemicals that produce bad odors or harmful vapors. Because it is enclosed, the fume hood may also be used to prevent contamination by serving as a sterile environment for certain laboratory procedures. Some chemicals may only be stored in a lockable ventilated storage cabinet. Ventilated storage cabinets are designed to prevent the buildup of gases that can cause an explosion or fire.

Summary

To work in a laboratory, biotechnology researchers must be able to handle microorganisms, chemicals, radioactivity, electrical hazards, and physical hazards safely. Researchers must wear personal protective equipment and be aware of laboratory hazards.

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Lesson 1:
The Mechanics of Cells and DNA

Cells are the fundamental units of life. Biotechnology research is usually done on the cellular or subcellular level. Knowing the cellular components and how the parts of a cell work is therefore necessary. Of particular importance is the core component of biotechnology research, DNA.

The Parts of Cells

All cells contain DNA. However, the structures found in the cells may vary. The cells found in plants and animals are similar, but they do have some differences. Bacteria cells are very different from plant and animal cells.

An animal cell (Figure 1.1) has a cell membrane, or plasma membrane, that forms the boundary of the cell. The cell membrane is primarily a lipid (fatty substance), carbohydrate, and protein structure. The membrane's primary function is to control the movement of substances into and out of the cell.

Inside the cell membrane is the cytoplasm, which consists of the contents of the cell, excluding the nucleus. The fluid of the cytoplasm helps control the movement of many substances within the cell. The cytoplasm includes many structures, called organelles, that fill different specialized functions in the cell.

Mitochondria are the powerhouses of the cell. They break down nutrients to provide energy to the cell. Hundreds of mitochondria may be found in a single cell.

The endoplasmic reticulum is a large network of membranes that transports material within the cell. Ribosomes are found on the endoplasmic reticulum. They are the sites where protein molecules are assembled, or synthesized. These protein molecules are important to the cell and to the organism as a whole because they control the chemical activities of cells.

The Golgi apparatus works with the endoplasmic reticulum in transporting proteins. It packages protein molecules for transport within and outside the cell.

Vacuoles are the storage units of the cells. They store water, enzymes, pigments, and other substances.

The control center of a cell is called the nucleus, which is defined by a pair of nuclear membranes. Inside the nucleus, chromosomes consisting of DNA can be found. Chromosomes are essentially tightly wrapped pieces of DNA that function as a unit. Genes are segments of DNA on chromosomes that produce a polypeptide (protein). Genes are responsible for the expression of genetic traits because the proteins produced by genes control the appearance, growth, and functioning of the organism.

Plant cells (Figure 1.2) contain these structures, but they also have a few differences. They have more vacuoles, which can be very large in mature plant

Figure 1.1 - Animal Cell

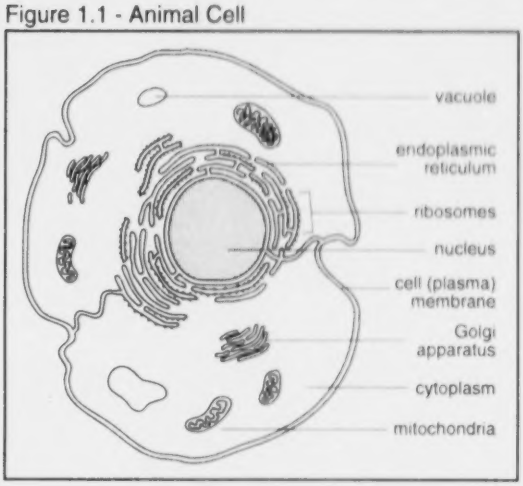


Figure 1.2 - Plant Cell

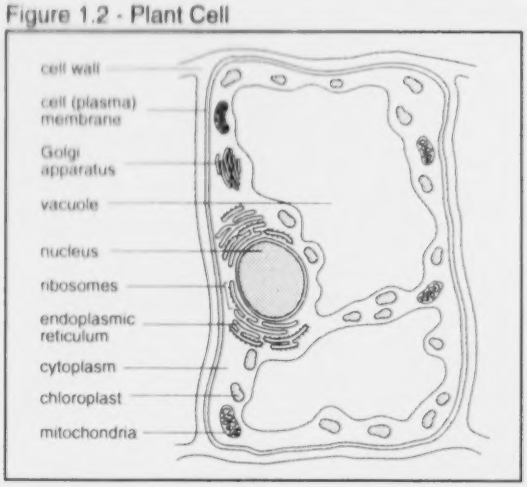


Figure 1.3 - Plasmid

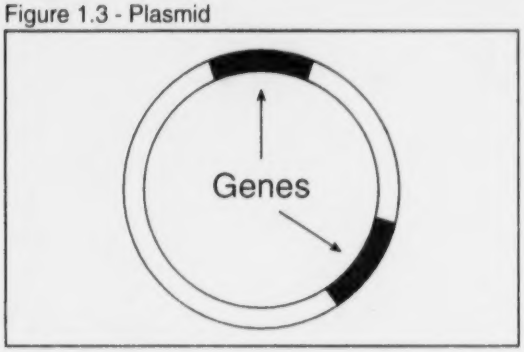
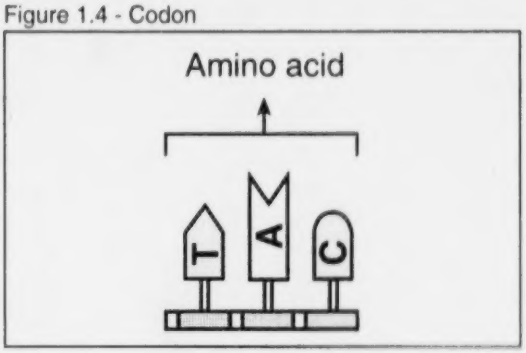


Figure 1.4 - Codon



cells. Plant cells have chloroplasts; they contain the chlorophyll used in photosynthesis. The cells also have a rigid outside layer called a cell wall that is composed of cellulose. The cell wall provides support for the plant cell and works collectively with the walls of other cells to support the plant. The cell wall has openings that allow substances to pass through it. The cell membrane in plant cells is just inside the cell wall.

Bacteria have a cell wall and cell membrane. They also have ribosomes that carry out protein synthesis. Unlike animal and plant cells, the chromosomal material is not contained within a nuclear membrane but instead forms a nucleoid region. A unique structure found only in bacteria cells is the plasmid (Figure 1.3). One or more plasmids can be found in a cell. Plasmids are essentially small circular pieces of DNA that code for specific traits and replicate independently of the chromosomal DNA. They normally contain only a few genes. Plasmids play an important role in biotechnology because they can be easily modified to produce pharmaceuticals.

DNA

Genetic modification involves the manipulation of DNA, or deoxyribonucleic acid. DNA is the genetic material of the cell. It is composed of small chemical units called nucleotides. A nucleotide consists of three parts: a phosphate group, a sugar unit (deoxyribose), and a base unit that contains nitrogen. DNA has four different nitrogen bases, creating four different nucleotides. These nucleotides are named after the nitrogen base. The four nitrogen bases are adenine (A), guanine (G), thymine (T), and cytosine (C). The nitrogen base units contain the code used to build proteins. A single strand of DNA may contain more than 100 million base pairs. DNA is not a simple molecule.

The Structure and Function of DNA

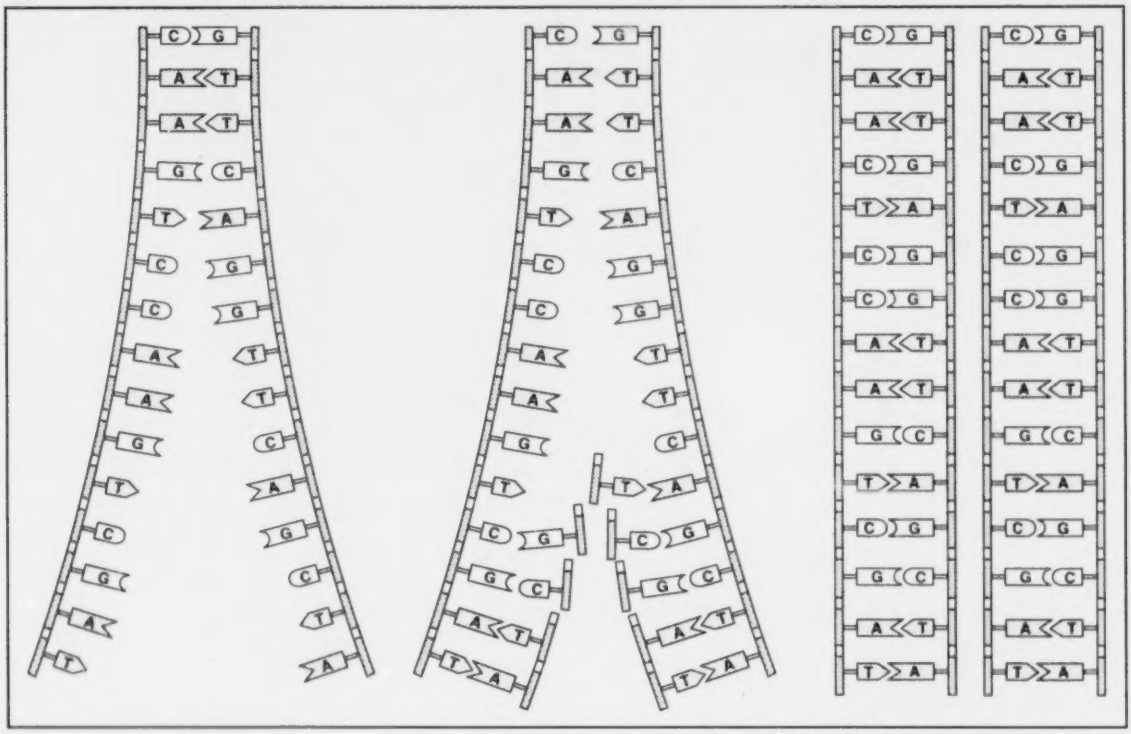
James Watson, a biologist, and Francis Crick, a physicist, were the first to discover the structure of DNA. They won the Nobel Prize in 1962 for their work. Watson and Crick found that two strands of nucleic acid are intertwined in a double helix structure. It looks like a twisted or spiraling ladder. The phosphate and sugar units form the sides of the ladder, while the nitrogen base units form the rungs. The nitrogen base adenine will only bond to thymine, and guanine will only bond to cytosine. Hydrogen chemical bonds join the base units.

The DNA in a plant, animal, or bacteria cell is essentially the same except for the sequence of bases it contains. This similarity of DNA makes the manipulation and transfer of DNA between these different life-forms possible. If the structure or function of plant DNA was different from animal DNA, then DNA from a plant could not be spliced into the DNA of an animal.

DNA is the blueprint of a cell. A builder of a house uses a blueprint to see where and how to install the walls, windows, plumbing, electricity, and many other things. In the same way, the cell uses its DNA to determine what types of proteins to build, or synthesize. The proteins produced during protein synthesis by the cells in an organism function as the chemical basis for the development of the organism.

Codons are sections of DNA three nucleotides long (Figure 1.4). Codons code for one of the twenty amino acids that are the building blocks of proteins. The codons are lined up end to end to form the DNA strand. Using this code, amino acids are lined up and linked together to form polypeptides. Two or more polypeptides are then linked together to form proteins. The kind and sequence of amino acids makes the shape of one polypeptide different from

Figure 1.5 - DNA Replication



another. The shape of a protein is strongly related to how the protein will function.

DNA not only codes for protein production in a cell but also passes this code on to new cells formed by cell division. Essentially, DNA copies itself before a cell divides. This process is called DNA replication.

DNA Replication

Cell division occurs when a cell grows and begins to get too large. When a nonsex cell in a plant or animal divides, the DNA in that cell must first replicate itself so that the two new cells have the same genetic material. Otherwise, each time a cell divided, it would lose half of its DNA. In DNA replication (Figure 1.5), the genetic material copies itself using a strand of DNA as a template. Replication begins when a protein made by a cell undergoing division binds to a section of the DNA called the origin. This event signals an enzyme to begin breaking the hydrogen bonds that hold the two strands of the helix together, causing the double helix structure of the DNA to "unzip." As the DNA strands come apart, a complex enzyme called DNA polymerase that is found in the nucleus of cells binds to each DNA strand segment and begins to add a new base unit to the strand. The added base must be compatible with the base on the parent DNA strand. Another enzyme then bonds the new nucleotides together with the parent DNA strand. Each DNA molecule now consists of one parent strand and one newly formed strand. With replication complete, the cell can then divide.

Summary

Cells have many organelles that must function together in order for the cell to survive. Each organelle has one or more functions that help the cell live, grow, and divide. DNA is very important to the cell since the code for building proteins is contained in the cell's DNA. The process of DNA replication allows the genetic code to be passed on to daughter cells.

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Lesson 2:
Cell Reproduction and Genetics

After organisms begin life, they grow and eventually reach maturity and reproduce. Their offspring then begin to grow and develop. A similar life cycle goes on at the cellular level. Young cells grow and mature until they are stimulated to reproduce. Cell reproduction takes place by cell division, in which the material in a cell is divided to produce two new cells. Cell division produces both body tissue cells and sex cells needed to produce offspring.

Mitosis

Mitosis is a type of cell division that takes place in somatic cells. Somatic cells include all the cells in an organism except the sex cells, or gametes (ova or sperm). Before mitosis begins, a cell replicates its genetic material. Each of the two new cells created by mitosis will therefore contain the same number of paired chromosomes as the parent cell. They will have two complete sets of chromosomes, or a diploid number of chromosomes. The process of mitosis involves four stages, which are illustrated in Figure 2.1.

The first stage of mitosis is prophase. The chromosomal material coils and condenses, and a double-stranded chromosomal structure becomes visible. This structure consists of two paired chromatids created by the duplication of DNA. Each double-stranded chromosomal unit has a point where the two chromatids connect. This point of connection, which is a body called the centromere, can occur at any point along the chromatids. The nuclear membrane then gradually dissolves. A network made up of complex protein units like hollow tubes, which are known as microtubules, begins forming around structures called centrioles, which start to move to opposite ends of the cell. The centrioles serve as anchors for the network of microtubules. This entire network is called the spindle. Spindle fibers extend from the centrioles toward the center of the cell. At this point, prophase ends.

Metaphase is the next stage of the process. The chromosomal units move to the center of the cell and form a line between the two poles formed by the centrioles. Each spindle fiber attaches to the centromere of one of the chromosomal units.

The third stage is called anaphase. The centromeres break and allow the spindle fibers to pull the two chromatids of the chromosomal unit apart. The chromosomes move toward opposite poles of the cell. The poles move even farther apart, elongating the cell. At the end of anaphase, the two poles of the cell each have a complete set of chromosomes.

The last phase, telophase, begins differently in animal and plant cells. In animal cells, the cell membrane pinches in at the center of the cell until the cell is completely divided into two cells. In plant cells, a structure called a cell plate forms and begins

Figure 2.1 - Mitosis

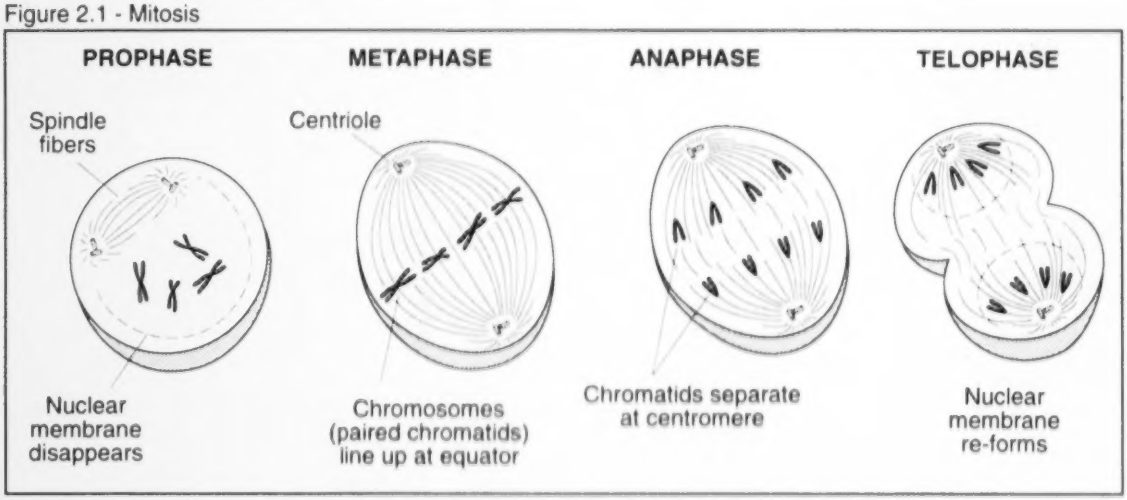
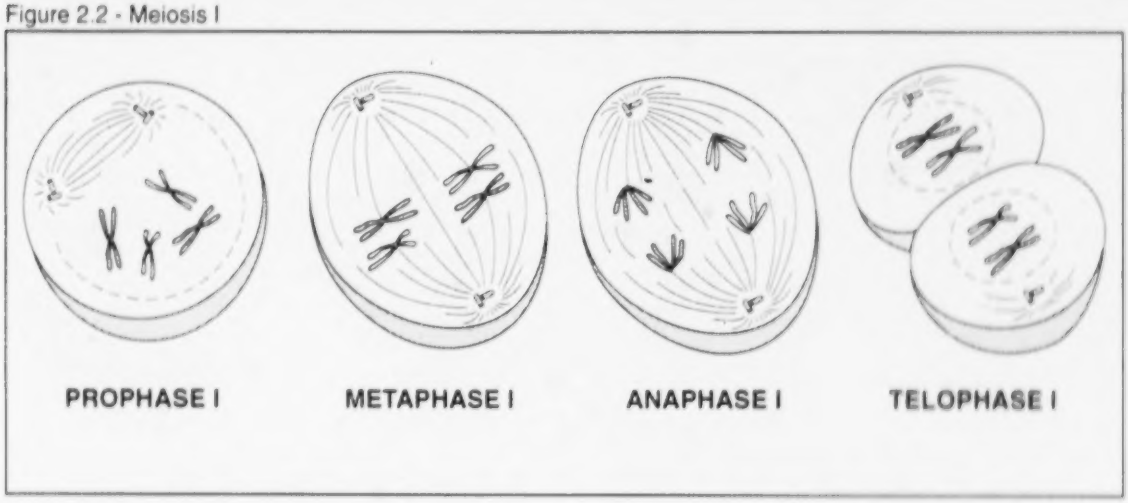


Figure 2.2 - Meiosis I



to divide the cell into two cells. A cell membrane forms on both sides of the cell plate, and eventually the cell plate changes into a cell wall. After the cell membrane or cell plate begins to form, a nuclear membrane develops around the two sets of chromosomes. The chromosomes themselves begin to uncoil and lose their distinct outlines. Mitosis ends when this process is complete.

Meiosis

Meiosis is also a type of cell division, but it produces gametes rather than somatic cells. Meiosis produces four gametes, since it consists of two phases of cell division. The gametes produced contain only half the number of chromosomes of the original parent cell, or a single set of chromosomes. It is for this reason that these gametes are referred to as haploid cells.

The first cell division process, or meiosis I (Figure 2.2), is somewhat similar to mitosis. The chromosomes replicate before the beginning of meiosis, just as they do before mitosis. During prophase I of meiosis, homologous chromosomes pair together. Homologous chromosomes are paired chromosomes that contain the same set of genes. One of the homologous chromosomes came from one of the organism's parents, and the other came from the other parent. They form a tetrad, a grouping of four chromatids side by side. The nonpaired chromatids may exchange segments through a process called "crossing over," in which a segment from one chromatid breaks off and reattaches to another. The process results in a change in the makeup of the chromosomes (see Figure 2.3). This exchange happens randomly. As in mitosis, the centrioles move apart and the spindle forms. The nuclear membrane dissolves.

Metaphase I is marked by homologous chromosomes lining up in the center of the cell. The spindle fiber ends attach to the centromeres of paired chromatids.

During anaphase I, homologous chromosomes separate and are pulled to different poles of the cell. The two cells formed after telophase will therefore not be genetically identical.

Telophase I can be identified by two distinct events. The first event is the formation of the cell membrane in animal cells or development of the cell plate and cell membrane in plant cells. The second event is the formation of nuclear membranes around the two new nuclei. The result is two haploid daughter cells.

After meiosis I, the two cells go through a short period of rest and then begin meiosis II, shown in

Figure 2.3 - Crossing-Over

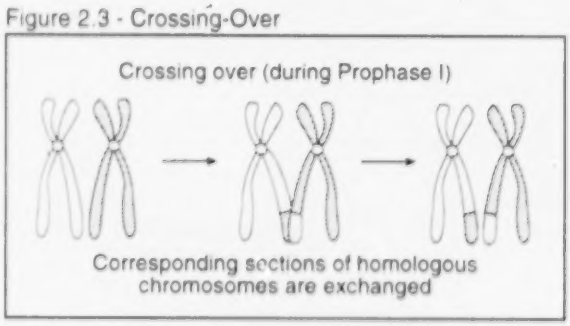


Figure 2.4 - Meiosis II

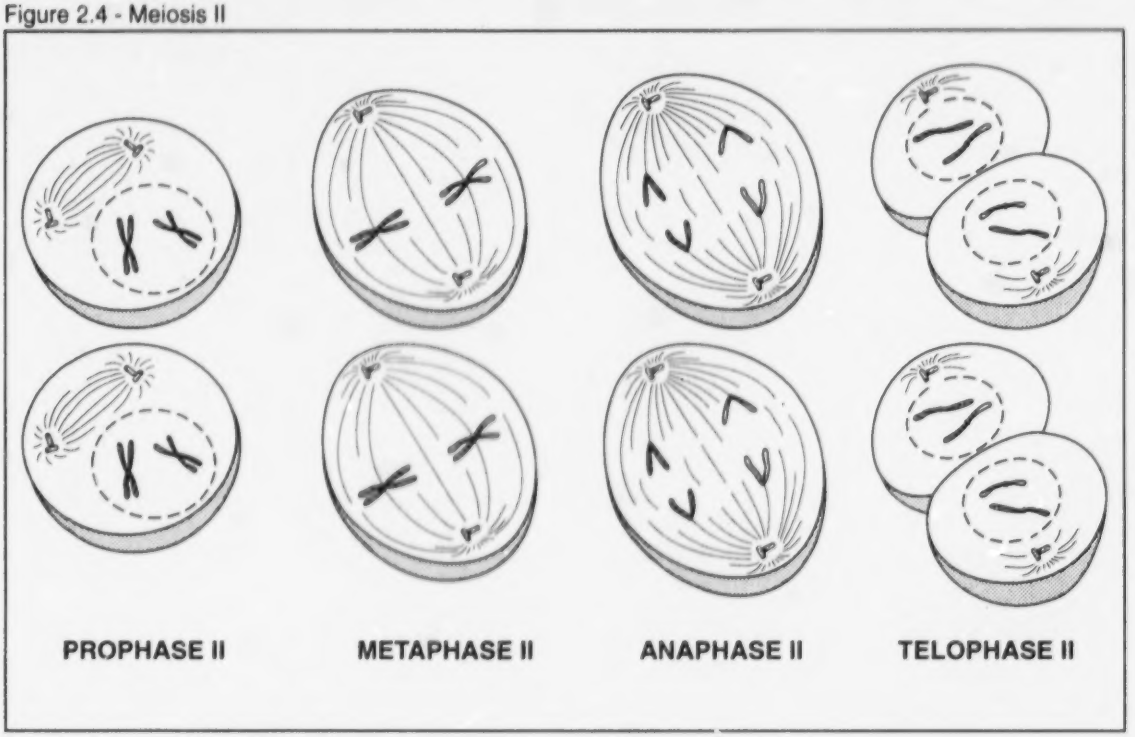


Figure 2.4. Unlike mitosis or meiosis I, the two cells do not undergo DNA replication. Meiosis II begins with the development of the spindle fibers and the movement of paired chromatids to the center of the cell during prophase II. During metaphase II, the chromosomal units line up in a row between the two poles and become attached to the spindle fibers. In anaphase II, the chromatids separate and move toward the opposite poles. In telophase II, the center of each of the two cells closes off with the formation of a cell membrane or cell plate, nuclei form, and the chromosomes uncoil. Meiosis yields four haploid daughter cells that are not identical to the parent cell.

Differences Between Mitosis and Meiosis

Mitosis and meiosis have four major differences. One of the more obvious differences is that mitosis produces two cells from one parent cell, while meiosis produces four cells from one parent cell. Another obvious difference is that mitosis produces diploid somatic cells, while meiosis produces haploid gametes. However, a more subtle difference is that while mitosis produces two identical cells, meiosis produces four nonidentical cells. During mitosis, chromosomes double and contribute an identical chromosome to each daughter cell, while in meiosis homologous chromosomes split and contribute nonidentical chromosomes to each daughter cell. The last major difference between mitosis and meiosis is that in meiosis a tetrad forms and allows "crossing over" of genes to occur between homologous chromosomes.

Dominant and Recessive Genes

Most chromosomes in all species of plants and animals work in pairs. For example, cattle have 60 chromosomes in the nucleus of every somatic cell. These chromosomes function as 30 pairs of chromosomes. Each chromosome has a homologous chromosome that has genes that code for the same information but in a somewhat different way. Each gene in a gene pair is either dominant or recessive.

The interaction between dominant and recessive genes can be seen by looking at coat color in cattle. One section of one of the chromosomes codes for coat color. The gene for coat color is found at the same location on both chromosomes. If one of these genes codes for black and the other codes for white, what will the coat color of the animal be?

Since the black gene is a dominant gene in cattle, the animal in question would have a black coat. The dominant gene is expressed, or seen in the animal. A dominant gene masks or covers up the expression of a recessive gene, which will not be apparent as a physical trait of the animal. In this example, the recessive gene is the gene that codes for white.

Homozygous and Heterozygous Gene Pairs

The term allele is used to describe either of the two possible expressions of a gene or multiple genes that code for a specific trait. An allele is usually represented by a letter of the alphabet. If the gene acts as a dominant gene, a capital letter is used to represent it; a lowercase letter is used to represent a recessive gene. If a plant or animal has two dominant alleles or two recessive alleles for a specific trait, it is homozygous for that specific trait. The terms homozygous dominant and homozygous recessive are used to differentiate between the two types of homozygous traits. If, however, a plant or animal has one dominant allele and one recessive allele, it is heterozygous for that trait.

Genotypes and Phenotypes

The genotype of an animal or plant refers to the specific combination of the alleles it possesses for each genetic trait. It is the actual genetic make up of the organism; for the example given above, the genotype would be either BB, Bb, or bb. The phenotype is the expression or appearance of a trait as determined by the genotype.

Mutations

What happens when a base unit is mistakenly inserted, deleted, or miscoded during the replication of DNA? Such a mistake is called a mutation. A mutation is an alteration of the nucleotide sequence found in a DNA molecule. This alteration can happen during replication prior to the beginning of mitosis or meiosis; it affects the organism differently depending on when the mistake occurs. If the mutation occurs just prior to mitosis, the change in the genetic code will be passed on to the daughter cell and any cell descending from the parent cell. Cancer is an example of a somatic cell mutation in which the mutated cell rapidly reproduces.

Mutations can also occur just prior to meiosis. In this case, the mutation is passed on to an organism's offspring if the gametes are fertilized. The offspring would have the altered DNA in every one of its cells.

Some mutations can be very beneficial, some can have a negative effect, and others may have no visible effect on an organism. An example of a positive mutation is the mutation that led to the development of the Polled Hereford breed of cattle. This breed was developed in the early 1900s by a rancher who noticed that calves from his Hereford cattle occasionally did not develop horns.

Summary

Cell reproduction is carried out through the processes of mitosis and meiosis. The genetic material passed on through these processes includes dominant and recessive genes and heterozygous and homozygous gene pairs. The genes an organism possesses determine its genotype and phenotype. Sometimes mutations also have an effect on the organism.

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Lesson 3:
Genetic Modification

Genetic modification is a very complicated process performed by highly trained researchers. This lesson will cover the basic procedures used in genetic engineering.

Gene Mapping and Gene Sequencing

Before the driver of a car makes a change in the planned route, he or she should check a road map to find out which roads to add to the route and which roads to avoid. Making changes in the genetic code of a cell is much the same, except that in this case the driver or researcher is driving blind because DNA cannot be seen except under extremely powerful microscopes. The researcher needs a map of the chromosomes of an organism to be able to select specific genes for modification. Gene mapping is the process of finding the location of genes for specific traits on the chromosomes of an organism. An example is a genome map of a corn plant, which shows the parts of the chromosomes that are responsible for plant height.

Gene sequencing is a related process that shows the order of all the base units (A, T, C, G) as they line up on a particular gene. A gene sequence is really a map of a single gene, which may be comprised of 100,000 or more base pairs. Gene sequencing is important to scientists because it allows them to recognize how to cut out a particular gene or gene fragment so that it can be placed into the DNA of the cell being modified.

DNA Extraction

Once a desired gene has been identified, it must be removed from the cell. DNA extraction is a three-step process. The cell membrane or cell wall must first be broken down to release the cytoplasm. The nuclear membrane must also be broken to release the chromosomes. Researchers accomplish this with the use of a surfactant, a fatty acid compound much like a household detergent. These compounds consist of lipids, just like the cell membrane. The surfactant breaks down the cellular membranes at a rate determined by temperature. Heat accelerates this process.

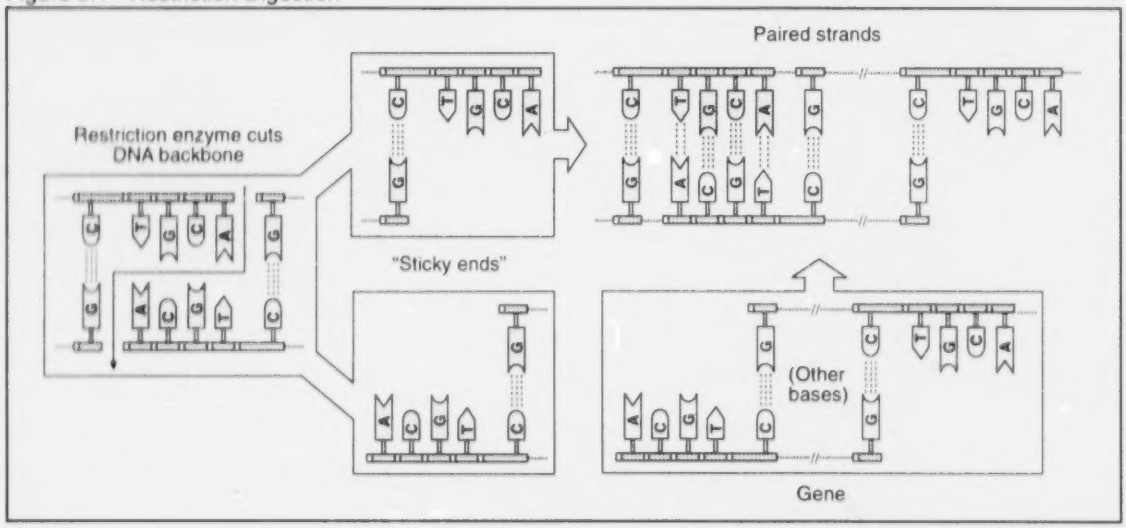
The second step involves the use of a protease, such as the enzyme papain. DNA strands in the chromosome wrap around protein molecules called histones. The protease will split this protein and the other protein contents of the cytoplasm.

The last step involves separating the DNA from the other cell components. Cold alcohol is added to the cellular solution. The DNA strands will clump together and rise to the top of the alcohol, since DNA is insoluble in alcohols. The DNA is then collected for later use.

Restriction Digestion

Restriction digestion is the process of cutting DNA into smaller fragments. The DNA is cut by

Figure 3.1 - Restriction Digestion

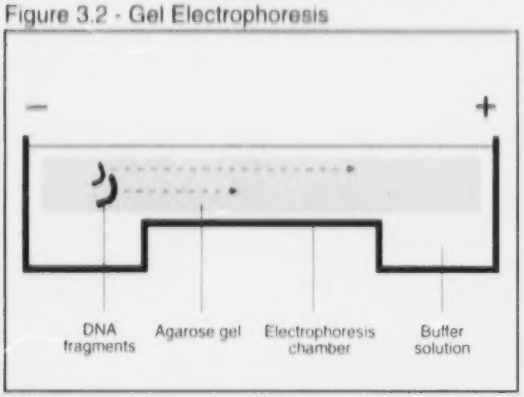


restriction enzymes, which are essentially biochemical scissors. Each restriction enzyme cuts DNA at a specific sequence of nucleotide base pairs, as illustrated in Figure 3.1. The sequence is called a restriction site. All DNA contains natural restriction sites. Researchers use restriction enzymes to cut genes or DNA fragments out of extracted DNA strands. Restriction digestion is useful to researchers in several ways. For example, researchers can identify whether a strand of DNA has a particular gene on it. They can also cut a gene from a strand for gene splicing.

Gel Electrophoresis

Gel electrophoresis is a process in which researchers apply an electric current to a gel to separate different lengths of DNA fragments into groups. The researchers can then recover a desired gene or gene fragment. Performing gel electrophoresis requires an electrophoresis box, a buffer solution, a special power supply, and a gel made from agarose or another agent. One end of the electrophoresis box has a positive pole and the other has a negative pole. The gel rests between them. The researcher places DNA fragments that have been stained with a dye in small wells or pockets at the end of the gel nearest the negative pole and applies an electric current to the gel. The buffer solution keeps the gel moist and facilitates the flow of the electrical current. The current causes the DNA fragments, which are negatively charged, to be repelled away from the negative pole and attracted to the positive pole (Figure 3.2). Short lengths of DNA will move through the gel faster than long lengths. The electric current is removed just before the short fragments reach the end of the gel. Fragments of DNA of the same size will be grouped at one spot on the gel. The markings caused by fragments of different sizes are called bands.

Figure 3.2 - Gel Electrophoresis



Gene-Splicing

Gene-splicing is the process of inserting a piece of DNA into a chromosome of a cell. It is also called ligation because the enzyme ligase is the biochemical glue that joins the pieces of DNA. Gene-splicing involves several steps. The process begins with the researcher cutting out a piece of DNA with a restriction enzyme. The correct restriction enzyme must be used so that the ends of the DNA will be "sticky," meaning that they contain bases that are complementary to the bases of the fragment to be incorporated. Gel electrophoresis must be performed to separate the DNA fragments by size and isolate the appropriate fragment. The researcher then joins the ends of the selected fragment to the DNA being transformed through a chemical reaction called a ligase reaction. Ligase chemically joins two DNA fragments by causing a bond to form between the phosphate portion of each fragment. The reaction is often done in a test tube. The result is a cell containing DNA from two different sources that forms a new genetic code, which is therefore called recombinant DNA.

This cell is then grown into an organism. In transgenic animals, the gene is spliced into the chromosomes of a fertilized egg, which is then implanted in the female reproductive tract. In plants, the plant cell with the transferred genetic material (often referred to as a transgene) is stimulated to grow into a plant. In each case, the organism has a copy of the new genetic information in every cell.

Summary

Genetic engineering is accomplished through the use of several processes. Gene mapping is used to locate the desired trait. DNA extraction isolates the DNA containing the desired gene. Restriction digestion then cuts the extracted DNA into specific pieces. Electrophoresis separates the DNA fragments into groups of like size. Gene-splicing joins the isolated piece of DNA to the DNA being modified. These basic genetic engineering technologies are used in research laboratories across the country.

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Lesson 1:
Artificial Insemination

Animal biotechnology began when humans began selecting and pairing more desirable animals during breeding to produce offspring of higher quality. Artificial insemination (AI) is an extension of selective breeding that gives livestock managers more options for improving offspring. The advantages and disadvantages of AI must be examined if it is to be used effectively.

Artificial Insemination

In 1780, an Italian researcher first developed a procedure for impregnating female animals without the presence of a male animal at breeding time. However, artificial insemination was not used by breeders until the late nineteenth and early twentieth centuries. Artificial insemination (AI) is the process of collecting semen from a male animal and placing it in the reproductive tract of a female animal. It is a form of biotechnology that is commonly used by livestock producers across the United States.

The Benefits of Artificial Insemination

Both artificial insemination and natural breeding have certain benefits. A major benefit of AI is that it allows producers to select and use male animals in their breeding programs that are proven performers, regardless of where the animals are physically located. Another benefit of AI is that reproductive or venereal diseases are not spread between breeding animals. A third benefit of AI is that it can reduce or eliminate the cost of owning and maintaining male animals for breeding purposes. The cost of the semen, the insemination process, and the hormones needed to manipulate the estrous cycle of female animals offset some of the economic benefits, but an AI system can still be more cost effective than a natural breeding system. One of the broader benefits of AI for the livestock industry as a whole is that the genetic improvement of livestock populations through the use of superior animals occurs much more quickly with AI, because of a dramatic increase in the number of offspring a male animal can produce (sire) per year. A single bull can only breed about 60 cows naturally in a year, but that same bull can be used to inseminate nearly 20,000 cows a year with AI.

Equipment for Artificial Insemination

Several different pieces of equipment are used for artificial insemination. Semen collection is most commonly done through the use of a dummy, which is a female replica. Male animals are trained to mount the dummy, and the penis is guided into an artificial vagina. The artificial vagina (see Figure 1.1) is a water-filled plastic sheath and has a collection tube in one end that holds the semen after ejaculation. A microscope is used when analyzing the collected semen. The semen is put into long, thin plastic tubes called semen straws. Each straw holds the amount of semen needed to breed one female. These straws are frozen and stored in an aluminum semen tank (Figure 1.2) containing liquid nitrogen. The straws are placed in an insemination instrument at the time of breeding. The insemination instrument is a long syringe-like tool that holds the straw and deposits the semen into the female reproductive tract.

Figure 1.1 - Artificial Vagina

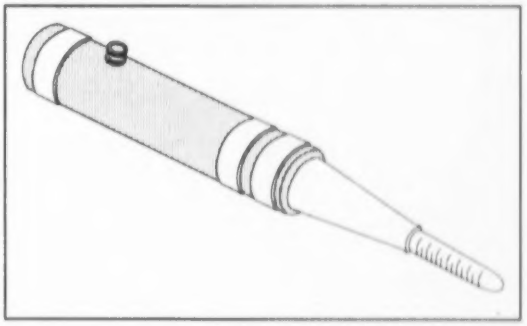
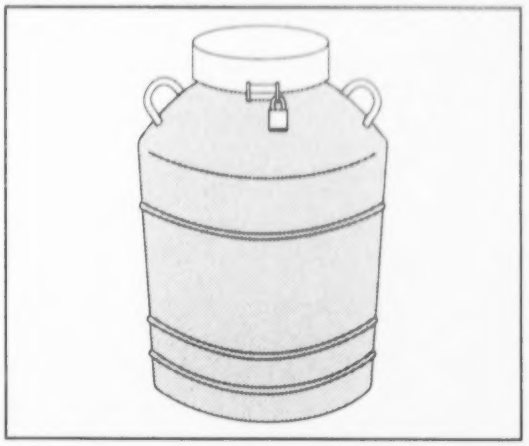


Figure 1.2 - Semen Tank



The Process of Artificial Insemination

Artificial insemination begins with the collection, inspection, and preparation of the semen. The collection of semen is important, since poor collection techniques will yield poor quality semen. After semen is collected using an artificial vagina, it is analyzed to examine the motility (active movement), shape, and quantity of the sperm. When the semen has been inspected, an extender is added to the semen to increase the volume. Several different types of extenders are used, but the most common are citrate, egg-yolk phosphate, and homogenized milk. These extenders protect and provide nourishment to the sperm when they are frozen. After the extenders have been added to the semen, it is placed in straws and frozen in liquid nitrogen at -320 degrees Fahrenheit.

The next part of the AI process begins when a producer decides to breed his or her animals. Producers must carefully manage the timing of insemination. Good semen and correct insemination procedures will not result in successful fertilization without proper timing. Each animal species has a different estrous cycle, which dictates the timing of insemination. Generally, insemination should occur shortly before ovulation.

When the time is right, the semen is thawed using proper thawing procedures to ensure that the sperm are not damaged. Once the semen is thawed, the straw is placed in the inseminating instrument, which is then inserted into the vagina of the animal being bred. The instrument is guided through the cervix, and the semen is placed just at the end of the cervix or the beginning of the uterus. A trained technician should perform this part of the process.

Manipulation of the Estrous Cycle

Female animals naturally produce the hormones that control the estrous cycle. However, through the injection of certain hormones, a producer can cause females to begin estrous as a group. This process, which is called estrous synchronization, simplifies the management of an artificial insemination program, because the animals in the group can all be bred within one or two days of each other.

Summary

Artificial insemination is an animal biotechnology that has a significant impact on the livestock industry. Artificial insemination is the process of collecting sperm from a male animal and placing it in the reproductive tract of a female animal. AI requires special equipment and close monitoring. The timing of insemination is critical to its success.

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Lesson 2:
Embryo Transfer Technologies

Today's science is tomorrow's applied technology. Embryo transfer is a good example of this trend. Once a complicated procedure requiring surgery, it has become a technology that some livestock producers are using in their own barns. This lesson will describe how embryo transfer is done, as well as some more advanced embryo manipulation methods, such as cloning.

The Process of Embryo Transfer

Embryo transfer (ET) is the process of transplanting embryos (fertilized eggs) from a donor female to a recipient female. Although ET is possible in several species of livestock, including sheep, goats, horses and swine, it is most common in cattle, which will be the focus of this lesson. The embryo transfer process has six steps. The first step involves the synchronization of estrous in the donor and recipient, which makes it possible for the collected embryos to be transferred to the recipient without being frozen. Next, the donor must be superovulated. Injecting the donor with a hormone like prostaglandin causes superovulation, or the release of multiple ova. The third step involves breeding the donor cow, either naturally or by artificial insemination. Next, the fertilized ova are collected from the donor through a process called embryo flushing in which fluid is used to wash the embryos out of the female reproductive tract. The fifth step in the embryo transfer process involves isolating and examining the embryos. Healthy embryos are transferred to recipients or frozen for later transfer.

Advantages of Embryo Transfer

Embryo transfer has several distinct advantages over natural breeding. It can increase the reproductive potential of superior females by allowing the female to produce multiple offspring each year. In addition, embryo transfer increases the rate of genetic improvement in a herd. The average cow can produce four to five calves per year using embryo transfer technology. With a superior cow providing four to five calves per year, high quality herd replacement heifers and bulls accumulate faster. Another advantage of ET involves progeny testing, in which offspring are evaluated for growth characteristics to determine whether an animal produces quality offspring. Using ET, female animals can be more easily and accurately progeny tested since they produce offspring more quickly; in three years, a cow should produce the ten calves needed for progeny rating. Finally, since shipping live animals internationally is a difficult and expensive process, embryo transfer has been employed as a way to use breeding stock from other countries. ET has been used to import and export rare breeds and the offspring of genetically superior animals.

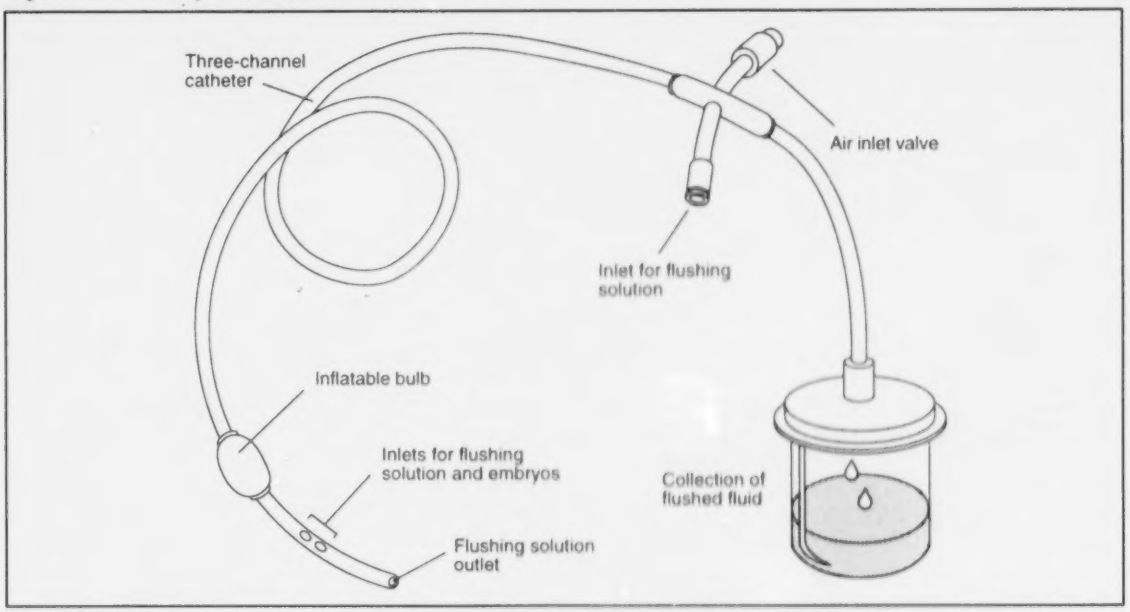
Embryo Transfer Equipment

Embryo transfer requires the use of some specialized equipment. The equipment needed to flush the donor cow includes a special catheter that has three narrow tubes encased in one long tube (see Figure 2.1). One tube inflates the bulb found near the end of the catheter. Another tube injects the flushing solution into the uterine horn to flush out the embryos. The third tube collects the flushing solution and embryos from the donor's reproductive tract. The catheter is inserted into the vagina and through the cervix with a device called a stylet. A collection cylinder holds the flushing solution and embryos after they have been removed from the donor. The technician needs a shoulder-length glove and lubricant to palpate the donor and recipient. Syringes are needed to inflate the bulb in the catheter, inject hormones, and give a local anesthesia. The equipment needed to examine the embryos includes a microscope, a pipette embryo-handling tool, and a gridded search dish. Transferring the embryo to the recipient requires the use of a plastic embryo straw, which holds the embryo for transfer, and an embryo transfer gun, which is used to expel the embryo into the reproductive tract.

Management of Superovulation

When prostaglandin is used to manipulate the heat cycle, preparation of the donor cow begins ten days after she is in standing heat with an injection of the hormone FSH, or follicle stimulating hormone. The injection of large amounts of FSH causes the ovaries of the donor

Figure 2.1 - Embryo Transfer Catheter



to release multiple ova. These injections are given once in the morning and once in the evening, until a total of seven injections have been given. On the third day of the procedure, prostaglandin is injected into the donor in the morning and evening. These two injections will cause the donor to come into estrus in 48 hours, and she can then be bred either naturally or through artificial insemination. The management of the process of superovulation is slightly different when other hormones are used.

The Embryo Flush Process

The embryo flush process is done seven days after breeding. The technician injects an epidural anesthesia into the space between two cervical vertebrae. The epidural causes the rectal muscles to relax, which aids in the insertion of the technician's hand into the rectal tract to guide the catheter. The technician uses the stylet to insert the special catheter into the vagina, through the cervix, and into the right uterine horn. He or she must palpate the donor carefully to guide the catheter into the proper location. The bulb near the end of the catheter is inflated to block off the uterine horn while it is being flushed.

A sterile flushing solution is allowed to flow into the uterine horn under the force of gravity until 500 milliliters of the solution is in the horn. The technician then starts to massage it to loosen the embryos. When the uterine horn is filled with flushing fluid, the technician opens the outlet tube of the catheter and collects the fluid and embryos in the collection cylinder. This process is repeated with the left uterine horn.

Because of their weight, the embryos settle to the bottom of the collection cylinder. The fluid above the embryos is carefully siphoned off. The embryos are ready to be counted and characterized, or examined for quality. They must be normal in appearance and of the correct size to be usable.

Transferring the Embryo into the Recipient

After the collected embryos have been washed and examined, technicians load embryos that are to be transferred to recipients into embryo straws. They are then prepared to be either transferred into recipient cows or frozen in a container of liquid nitrogen at -320 degrees Fahrenheit. The recipients have already been prepared to receive the embryos through estrous synchronization. A technician loads an embryo transfer gun with a

straw and inserts it into the recipient cow's vagina. He or she guides it through the cervix and into the uterus, where the embryo is expelled.

Cloning

Cloning is the asexual reproduction of an organism in which the resulting organisms are identical. The livestock industry uses two basic methods of cloning. In the first method, the researcher physically splits the embryo into two halves as it is dividing. Each half is transferred to a recipient and develops normally. Embryo splitting doubles the number of embryos available for transfer.

Nuclear transfer is a second method of cloning. Nuclear transfer involves removing the nucleus of an unfertilized ovum. A cell is then extracted from a parent organism and fused into the ovum without a nucleus using an electrical pulse. The new cell has a diploid number of chromosomes and will develop as if it were a natural embryo. However, it must be stimulated to act like a fertilized ova and begin dividing. Nuclear transfer technology can multiply the number of embryos by 16, 32 or even 64, depending on the number of cells available in the parent embryo.

Benefits of Cloning

Cloning has several advantages. It can increase the number of highly prized animals produced because it multiplies the number of collected embryos. Cloned animals are valuable to researchers doing live animal experiments. Fewer animals can be used in these tests because all of the animals--control animals and experimental animals--are identical. Animals genetically altered to produce pharmaceuticals could be cloned as well, which would reduce the cost of producing the animals.

In Vitro Fertilization

In vitro literally means "in glass." In vitro fertilization (IVF) is a process in which immature follicles (ova) are collected from the ovaries of a female animal, stimulated to mature, and fertilized outside the female reproductive tract in a test tube. The fertilized embryos can be transferred to recipient animals.

The process of IVF begins a few days before ovulation. A technician inserts a special probe containing an ultrasound sensor into the vagina and moves one of the ovaries to a position directly above the vaginal wall. The ultrasound equipment is then used to locate the follicles. The technician inserts a needle through the vaginal wall and into the ovary. The needle is attached to a vacuum device that sucks the follicles into a collection bottle. The follicles that are collected are stimulated to mature in the laboratory and are then fertilized.

Summary

Embryo transfer, which has only been in use since the early 1980s, is a relatively new technology in the livestock industry, but the number of dairy and beef cattle producers using it is growing rapidly. Embryo transfer is the process of transplanting embryos from a donor female to a recipient. The procedure involves superovulating a donor, flushing the embryos out of the donor, and transferring the collected embryos to a recipient. More advanced techniques such as embryo splitting, nuclear transfer, and in vitro fertilization are also beginning to be used in the livestock industry.

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Lesson 3:
Applications of Biotechnology in Animal Agriculture

The previous two lessons discussed artificial insemination and embryo transfer. These applications of biotechnology have a direct impact on the genetic makeup of the animals produced. Other forms of biotechnology, such as the use of biotechnology to produce supplemental hormones and animal health products, affect animals more indirectly.

Supplemental Hormones

Supplemental hormones are chemical messengers administered to animals that stimulate them to grow, produce more milk, or improve their performance in another way. Many of the supplemental hormones produced are growth hormones. Human beings and animals naturally produce the growth hormone somatotropin in their pituitary glands, although the somatotropin produced by two species is very different. For example, bovine somatotropin has no noticeable effect when injected into a human being.

Bovine somatotropin (BST) is one of the best known supplemental hormones. In 1993, the FDA approved BST for use as a drug. When injected into a cow, BST causes a secondary hormone to be released that increases blood flow in the mammary glands. This blood flow increases the amount of milk produced by the cow by 10 to 15 percent.

Porcine somatotropin (PST) is another growth hormone. When PST is injected into a pig, it causes the pig to grow about 15 percent faster and consume 20 percent less feed. In addition, muscle mass, including the loin eye area, increases, while backfat is reduced. Researchers are searching for a way to put PST in an implant to eliminate the need for regular injections. The FDA has not yet approved the use of PST.

Growth hormone releasing factor (GHRF) is not itself a growth hormone, but it stimulates the pituitary gland to release larger amounts of growth hormones. Researchers are looking for ways to use GHRF to improve animal production.

Supplemental hormones have shown promise for use in the poultry industry. Research has shown that the use of a chicken growth hormone shortens the time needed for broilers to reach market size by 15 percent. A chicken molting hormone has shown promise in increasing egg production levels.

Producing Supplemental Hormones and Animal Health Products

Before modern biotechnology was developed, the only way to obtain somatotropin was to collect it from the brains of slaughtered animals. However, only a small amount of the hormone could be collected from each animal. The somatotropin was therefore very expensive.

Bacteria can now be engineered to make proteins that they do not normally produce, allowing supplemental hormones like BST to be synthesized. To produce BST, researchers located and isolated the gene that stimulates the production of bovine somatotropin. They inserted it into a plasmid taken from a bacterium. Scientists opened up the plasmid ring with a restriction enzyme and spliced the gene into the opening. The plasmid was reinserted into the bacterium. Modified bacteria are placed in a fermentation tank under ideal conditions for the bacteria to grow and divide. After a substantial number of microorganisms are produced, somatotropin can be purified from the bacteria.

Poor animal health costs the U.S. livestock industry approximately $17 billion annually. Advances in biotechnology have strengthened the fight against animal disease. Biotechnology is used to improve the health of livestock in three major ways.

Monoclonal antibody technology is one way biotechnology is used to produce animal health products. When a virus, bacteria, or parasite attacks an animal, the animal's immune system responds by producing proteins called antibodies. Antibodies are very specific in their function; they are only produced in response to a particular antigen (a substance that triggers an immune response). When an animal is vaccinated with a

weakened form of the disease-causing organism, the animal's body produces antibodies that continue to look for the antigen for years after the vaccination. Monoclonal antibodies are produced by fusing a tumor cell to an immune system cell that produces antibodies against a specific antigen. This process yields a cell that divides rapidly (because of the tumor cell) and produces the desired antibody. Several tests for diseases have been developed from this technology, such as the quick sale barn test for brucellosis and the animal pregnancy test.

The second way biotechnology affects animal health is through the development of therapeutic proteins. In the past, veterinarians have not had a drug to use to fight viruses. When injected into an animal, therapeutic proteins like interferon and interleukin-2 attack viruses. They also stimulate the animal's immune system to attack the viruses. Like growth hormones, therapeutic proteins are produced by genetically modified bacteria. Preventing shipping fever, a disease found in cattle, has been a major focus of the use of therapeutic proteins. Shipping fever is the result of an attack by several viruses that the animal's immune system normally repels; this defense is weakened when an animal is under stress. Injections of therapeutic proteins may help prevent shipping fever.

The third way that biotechnology is influencing animal health is through genetically engineered vaccines. Early vaccines were made from dead or weakened disease-carrying organisms. These vaccines can take a long time to develop, must be refrigerated, and may have side effects. Vaccines developed using genetically modified bacteria contain only the antigen of the disease-causing organism. They stimulate the immune system to produce antibodies against the antigen. Genetically engineered vaccines are safer and can be produced relatively quickly. Examples of vaccines produced through biotechnology include vaccines for scours in pigs, foot-and-mouth disease, pink eye, and tapeworms in sheep.

DNA Fingerprinting in the Livestock Industry

DNA fingerprinting is the result of fragmenting DNA with a restriction enzyme and then segregating the fragments with gel electrophoresis to produce a distinctive pattern. It is being used in the livestock industry to positively identify individual animals. In the past, valuable animals like race horses have been stolen by switching an animal with a look-alike. DNA fingerprinting can accurately identify stolen animals. It can also verify that an animal is the offspring of a particular set of parents. Some breed associations require that a blood sample be submitted with the application for registration for an animal so that a DNA fingerprint can be made. DNA fingerprinting is also being used to identify transgenic animals for patenting purposes.

Emerging Applications of Biotechnology in Animal Agriculture

Research continues into the development of new and expanded applications of biotechnology in animal agriculture. Currently, genetically engineered vaccines for foot rot in cattle and strangles in horses are under development. The livestock feed industry is looking into the possibility of using genetically modified bacteria to produce protein for feeds; the bacteria containing the desired protein would be killed and the contents added to the feed. The feed industry is also researching methods of engineering rumen bacteria so that animals can better use feedstuffs that are normally hard to digest.

The cloning of adult animals is emerging as a new area of animal biotechnology. In early 1997, Dolly, a sheep cloned from a single cell taken from an adult animal, was introduced to the world. Although this type of cloning is possible, it is extremely expensive, and its applications are likely to be limited to a few highly specialized functions. For example, if animals were genetically modified to grow human organs, cloning these animals would allow their numbers to increase more quickly.

Summary

Biotechnology is playing a growing role in animal agriculture. From the use of bacteria-produced somatotropin to the development of genetically engineered vaccines, biotechnology is changing the livestock industry. As research continues, more applications of biotechnology will affect the production of livestock.

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Lesson 4:
The Impact of Biotechnology in Animal Agriculture

With more than twenty companies dedicated to the development of animal biotechnology products and many other large companies that conduct research in this field, new animal biotechnology products will likely be on the market soon. A variety of career opportunities exist in this new but rapidly growing field. A number of economic and social impacts accompany this growth in animal biotechnology. The industry will have to address these issues.

Careers in Animal Biotechnology

Careers in animal biotechnology include jobs that use the products of animal biotechnology (such as a livestock producer) and positions in the companies that develop and market these products. Biotechnology companies have a variety of job positions. Large companies usually have more specialized positions, while smaller companies have positions that include a broad range of responsibilities. However, most companies have one or more employees working in eight major areas. These major areas are research and development, quality control, clinical research, manufacturing and production, regulatory affairs, information systems, marketing and sales, and administration. The jobs in the different areas vary in the amount of education they require, ranging from a high school diploma to a doctorate in a specific scientific field.

Research and development - The area of research and development (R&D) involves the actual laboratory research needed to develop potentially useful products. Positions in this area include glass washer, laboratory assistant, research assistant, postdoctoral fellow (a term for a new scientist), and research director/principle investigator (experienced scientists).

Quality control - This area includes positions such as quality control analyst, environmental health and safety specialist, equipment validation engineer, and validation technician.

Clinical research - After some products are developed, they must be tested on live animals in a clinical research setting. Positions in this area include clinical coordinator, clinical data specialist, clinical research associate, and animal handler/technician.

Manufacturing and production - The manufacturing and production area offers a variety of positions, including product development engineer, manufacturing engineer or technician, instrument calibration technician, and packaging operator.

Regulatory affairs - Regulatory affairs offers positions for specialists who work with regulatory agencies to obtain approval for products. Examples of positions available in this area include regulatory affairs specialist and documentation specialist.

Information systems - Positions in information systems include scientific programmer analyst and literature research assistant.

Marketing and sales - Biotechnology products must be marketed, which is the responsibility of those involved in the marketing and sales area. Positions in this area include market research analyst, sales representative, and customer service representative.

Administration - In administration, positions such as human resources representative, supply buyer, and patent administrator are available.

Economic Factors Affecting Producers

One of the most important questions livestock producers face when a new technology is put on the market is whether to use it. To answer this question, producers must consider the benefit-to-cost ratio. The ratio is a comparison of the economic benefits of using the product to the costs of using the product. For example, if a new genetically engineered feed additive costs $6 per feeder calf to use but increases feed efficiency by 20 percent, which saves $18 in feed costs, then the benefit-to-cost ratio would be 3 (18 ÷ 6). If the ratio has a value of two or greater, the product is considered cost effective.

A second economic consideration that producers must take into account is the cost of not using a biotechnology product, which is not a simple task. Producers must be able to provide a competitive product. If most producers begin to adopt a new technology, the price of livestock may drop, making the use of the product necessary.

The reliability of a biotechnology product is also important. Producers must evaluate the actual effects of using the product. If a product does not perform as well as expected or is not reliable in its performance, the value of the product is not as high.

Finally, livestock producers must consider not just the cost in actual dollars but the time required for the additional management and training that is often associated with the use of new products. This economic consideration is frequently overlooked when a new product is introduced.

Consumer Health and Safety Concerns

The public, those who buy meat, dairy, and egg products, are consumers of animal biotechnology. Many people are concerned or fearful about animal biotechnology because they do not understand the technology. This lack of understanding lends itself to the acceptance of rumors as fact. Consumers have also become skeptical about research findings due in part to research reports like those about substances "shown" to cause cancer, since the quality of some cancer research studies has come into question.

The effect of these factors on biotechnology is that when research is published that suggests that new biotechnology products are safe, many consumers are not convinced. Consumers of fresh vegetables have recently turned to higher-priced "natural" or "organic" foods because they see them as healthier than nonorganic foods. This consumer perspective may be transferred to animal products, producing a new market for "natural" meat, milk, and eggs.

Is there a justification for these consumer concerns? The answer to this question is both yes and no. Yes, because consumers should always be concerned about the safety and wholesomeness of the foods they buy. They should also be informed about the methods used to produce those foods. No, because animal biotechnology products must be shown to be safe before regulatory agencies approve them.

Global Social Impacts of Animal Biotechnology

Agriculture has historically had a worldwide social impact. As the world population grows, the need for animal products will increase as well. Biotechnology has the potential to increase the global supply of meat, dairy products, and eggs. The real question, which cannot be conclusively answered, is whether animal biotechnology can increase the production of animal products without an equal increase in production inputs. BST, for example, causes cows to produce more milk, but these cows require more feed. Unless those extra inputs are available, production cannot increase.

The mid-1990s has also seen a considerable amount of debate take place in Europe over the use of biotechnology by the developed world. For example, Europeans have debated the development of transgenic animals, such as genetically modified species of fish. Scientists have developed thirteen genetically modified species of fish that grow 20 to 100 percent faster than unmodified fish. If these modified fish are accidentally or intentionally released into some of the world's oceans, will the unmodified fish be able to compete for food? Will the fish spawn differently? What would be the result of a cross between a modified and an unmodified fish? Could one country release modified fish without the approval of other countries? These types of international concerns must be addressed. The international political environment will determine the extent of the use of animal biotechnology.

A third impact of animal biotechnology is that it may change the number of livestock producers needed in the United States and the world. If animal products can be produced more quickly and with fewer losses due to disease, will fewer producers be able to supply the meat, milk, and egg demands of the national and worldwide markets? The answer to this question is unclear. On one hand, if population growth causes demand to increase faster than production, the need for producers will grow. On the other hand,

if the production of animal products increases faster than the demand, fewer producers will be needed.

Summary

Livestock producers demand biotechnology products that make economic sense. Consumers demand food products that are safe and healthy. The world needs answers concerning the social impact of animal biotechnology. The field of animal biotechnology faces several challenges but promises many rewards. As animal biotechnology continues to advance, the number of career positions available in this field will increase.

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Lesson 1:
Traditional Plant Breeding

Traditional plant breeding technologies are described in this lesson. Basic breeding practices include natural crossbreeding, selective breeding, and hybridization. Modern plant biotechnology is founded in plant breeding practices that are thousands of years old.

Natural Crossbreeding

Natural crossbreeding is the name for the reproductive process in which two plant varieties, which have different genotypes, sexually reproduce without human intervention. Natural crossbreeding allows the random mixing of genes to occur within a species. Desirable and undesirable traits are combined within the plant species. Plants that receive more vigorous genes generally grow and reproduce better than plants that do not. Weaker plants will therefore very gradually diminish in number as stronger plants dominate. This gradual improvement of the species can be accelerated through selective breeding practices.

Selective Breeding

Selective breeding is the process of identifying plants with desirable traits and causing them to reproduce. Plants are selectively bred mainly for two reasons: to increase the production of the useful parts of the plant or to increase the ability of a plant to withstand harsh environments, disease, or plant pests. Selective breeding can be done asexually or sexually. Many horticulture crops are reproduced asexually. Most field crops have traditionally been reproduced by sexual breeding methods, but more recently the asexual method of plant tissue culture has been used. Sexual breeding methods include inbreeding and hybridization. Inbreeding is the crossing of closely related plants to cause their offspring's traits to become more homozygous. Hybridization occurs when two inbred plants that are genetically different are crossed to produce plants that are superior to both the parent plants.

Advantages and Disadvantages of Selective Breeding

Selective breeding has two advantages. It allows the plant breeder to increase the occurrence of desired plant traits; typically, the most important trait is crop yield. Selective breeding also helps to make the performance of a crop more predictable since the selected plants are multiplied by controlling their pollination to produce a more uniform crop of seeds. This seed crop is sold to farmers who produce the final product.

Selective breeding also has some disadvantages. While the occurrence of desired traits increases, the occurrence of undesirable traits may also increase. As the selected plants are bred, the plants become more homozygous for both desired and undesired traits. A second disadvantage is that the genetic diversity of a crop species decreases as more similar plants are selected. Some native varieties of crops have been lost due to the extensive use of fast-growing high-yield varieties that crowd out the plants that grow more slowly. Another disadvantage of selective breeding is that the uniformity of the crop plants can increase insect problems. Insects that like a certain crop can multiply quickly when the crop is more uniform and cause a greater amount of crop damage.

Hybrids

Hybrids are plants produced by crossing two inbred lines of plants that are greatly different genetically. Before a hybrid is produced, inbreeding is used to develop a consistent plant phenotype. Breeders force a plant to self-pollinate and then force its offspring to do the same. They repeat this process five to seven times so that the plants will consistently express the same phenotype.

Breeders use three common methods to produce a hybrid seed. The first method is called a single cross. When inbred plant Z is crossed with inbred plant Y, the result is a single cross hybrid, ZY. The second method of hybridization is called a three-way cross. A three-way cross is made by taking a single cross ZY and crossing it with another unrelated inbred plant X to produce a three-way cross hybrid, ZYX. The third type of hybridization is the double cross. In a double cross, breeders make two single crosses, and then they cross the two single cross hybrids.

A hybrid generally displays more vigorous growth than both of its parents. This extra vigor in its growth is called hybrid vigor, or heterosis. However, hybrid plants usually either are sterile or produce offspring that do not perform well and are inferior to

the hybrid. Extensive work must continually be done to supply hybrid seed to producers.

Summary

Breeders have replaced natural crossbreeding of plants with selective breeding and hybridization to produce superior plants. These crop development methods have laid the foundation for the modern methods of plant development--plant tissue culture and genetic manipulation.

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Lesson 2:
Plant Tissue Culture

The horticulture industry regularly uses a biotechnology technique called plant tissue culture as an effective method of propagating horticultural crops such as ferns and orchids. Plant tissue culture is also being used to grow whole plants from genetically modified plant cells. This lesson will introduce and explain the process of plant tissue culture. The steps in tissue culturing and the stages of tissue culture growth will also be examined.

Plant Tissue Culture

Plant tissue culture is an asexual method of reproduction. The plants produced will be exact clones of a single parent plant. Plant tissue culture involves selecting a piece of a parent plant and placing it in a sterile artificial media where it grows into a new plant.

Advantages and Disadvantages of Plant Tissue Culture

One of the main reasons that plant tissue culture was developed was that some plants are very difficult to propagate commercially. Tissue culturing allows plant growers to mass propagate clones of a highly desirable plant. They can produce thousands of plants from a few pieces of one plant. Another advantage of plant tissue culture is that pathogen-free plants can be produced since certain portions of a plant do not contain viruses that are found in the rest of the plant. A third advantage is the conservation of time, because plants can be propagated from tissue culture at any time during the year. A fourth advantage is the conservation of growing space. Tissue culture plants are divided multiple times and begin as very small plants that grow slightly more slowly than normal. The number of plants traditionally grown on one acre can therefore be grown on shelves in 50 to 60 square feet of space.

With the advantages come some disadvantages. Plant tissue culture is an expensive method of plant propagation requiring an extensive amount of sophisticated equipment and facilities. In addition, plant tissue cultures are susceptible to contamination by microorganisms. Tissue cultures are destroyed if contamination occurs. A third disadvantage is that commercial tissue culture requires skilled workers, which adds to the total cost of producing the plants.

Plant Tissue Culture Equipment

The equipment and supply needs for plant tissue culture can be broken down into three separate areas--preparation, transfer, and growth. Several types of equipment and supplies are needed when preparing to do a tissue culture. A refrigerator is needed to store the chemicals for the growing media. The pH of the growing media must be checked with a pH meter. A scale or balance is required to measure the quantities of the media ingredients. The ingredients are warmed on a heating plate. Finally, an autoclave is required to sterilize the media and the equipment used in transferring the plants. When transfer is carried out, a fume or air flow hood is used to reduce the movement of air (which may contain microorganisms) in the work area. The technician holds the plant tissue with a sterile forceps and uses a scalpel to divide the plant for culturing. Test tubes or petri dishes hold the growing media and the plant tissue after transfer. For some types of tissue culture, a dissecting microscope is used to help in the selection of the tissue for culturing. When the process is completed, the tissue cultures are put in a growth chamber, a room that controls exposure to heat and light.

Steps in Plant Tissue Culture

The first step in plant tissue culture is media preparation. The initial growing media varies slightly in composition depending on the plant species. However, it generally contains plant nutrients, mineral salts with vitamins, plant hormones that regulate growth, pure water, sugar, and agar (if a semi-solid media is needed).

The second step in the process is the selection and collection of the explant. The explant is the portion of the parent plant that will be used to grow new plants. Depending on the plant being propagated, a shoot tip, bud, section of a leaf with veins, node, or bud scale may be chosen. Different plants grow better from different types of explants. The explant is nearly always selected from rapidly growing tissue since this tissue is best able to produce the new plant. It is also important that healthy and disease-free parent tissue be used.

After the explant has been chosen, the next step is cleaning the explant. It must be disinfected. If the

explant is woody tissue, alcohol is used as a disinfectant; for most other plant tissues, a 10 percent bleach solution is used. The explant is soaked in the bleach solution for only ten minutes. If it is soaked longer than ten minutes, damage to the plant tissue can occur. Often a drop or two of detergent is added to the bleach solution as a wetting agent to help the disinfectant apply to surfaces more effectively. After it is soaked in the disinfectant, the explant is rinsed at least three times in pure water to remove any remaining bleach solution.

The fourth step involves transferring the explant to the growing media. The collected plant tissues are trimmed, and some types of tissues can be divided for growing more plants. A dissecting microscope is sometimes needed if the explant is very small. The explant is then transferred to the growing media. This procedure must take place in a sterile environment.

Stages of Tissue Culture Growth

The first stage of tissue culture growth is called the initiation and establishment stage. This stage lasts about four to six weeks. A callus composed of rapidly dividing cells forms and grows in response to the wounding or cutting of the plant tissue. A shoot or immature stem begins to grow during this first stage.

The second stage of tissue culture growth is the proliferation or multiplication stage. It lasts one to three months. During this stage, the shoot multiplies into many shoots. These new shoots can be divided to increase the number of plants produced. A slightly different growing media is used in this stage.

The third stage is the pretransplant stage. It lasts about three weeks. Roots begin to grow. A slightly different growing media is used. The plants begin to photosynthesize and require more light. Near the end of this stage, the young plants are stressed slightly in a process called hardening off, which involves exposing the young plants to conditions outside the sterile container in which they grow.

The fourth stage of plant tissue culture growth is called the transplanting stage. The growing plants are put into pots and moved to a shady, humid greenhouse. After a several weeks, the plants are again hardened off and then moved to a regular greenhouse where they will receive full sun and less humidity.

The Use of Tissue Culture in Genetic Engineering

When a single plant cell or group of cells is genetically modified, tissue culture is often used to rapidly grow a set of plants. These plants are genetically identical to the plant cell or cells used to create them. A second use of plant tissue culture is for the screening of a large number of plants for certain characteristics. If a more drought-tolerant plant is desired, then hundreds of tissue cultures can be taken from a wide range of plant varieties and mutations to find this characteristic. The tissue cultures from the plants are grown and exposed to drought conditions. Those plants that show promise are grown to full size. This screening allows researchers to focus on plant varieties that might contain desirable genetic traits.

Summary

Tissue culture has become an important tool for plant breeders and researchers. It allows breeders to quickly produce large numbers of mature clones of a parent plant. Researchers are able to genetically modify a plant cell or group of cells and then grow these modified cells into a mature plant. However, plant tissue culture is an expensive process and can fail if the cultures become contaminated. Tissue culturing involves four major steps: media preparation, choosing the explant, cleaning the explant, and transferring the explant to the growth media. Growth also occurs in four stages: initiation and establishment, proliferation, pretransplant, and transplant.

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Lesson 3:
Genetically Modified Plants

The era of genetic engineering in plant agriculture began with the approval of the first genetically modified food crop in 1994. Since then several genetically modified plants have been developed and approved for use. This lesson will examine how these modified plants were developed and how they function.

Developing Genetically Modified Plants

The first step in the development of a genetically modified plant is to find, isolate, and clone the gene or genes that cause the expression of the desired trait in an organism. Often the gene expressing a desired trait has not been identified or located in the DNA of that organism. The process of finding the needed gene can be very difficult. It is easier, however, if researchers have made a genome map of the particular organism, since they will have identified markers that will narrow the search considerably.

The second step involves the selection of a means of genetic transfer. A bacterium or virus can be used as a vector, the vehicle for moving the desired gene into the plant cells. The desired gene and a marker gene are inserted into the bacterium or virus, and the microorganism is placed in contact with the plant cells to be modified. The bacteria or virus infects the cells and transfers the desired gene to the plant cells.

A gene gun can also be used to transfer a desired gene into a plant cell. The desired gene and a marker gene are inserted into plasmid; the plasmid is then placed on the surface of very small (1 mm in diameter), heavy metal pellets. These pellets, usually made of gold, are shot into the plant cells with the use of a small high-pressure gun. High pressure is needed to penetrate the plant's cell wall.

A third method of gene transfer involves the use of chemicals to weaken or dissolve the cell wall. The desired gene could then physically be placed in the cell. After the gene is incorporated, the plant cell is stimulated to repair the cell wall.

The third step in developing genetically modified plants is the selection of the plant cells that incorporate the desired gene into their DNA. The plant cells that contain the desired gene will also contain the marker gene, which is designed to be easily identifiable. These cells will be grown into mature plants through tissue culturing.

How Herbicide-Tolerant Plants Function

Many herbicides kill plants by chemically blocking a metabolic pathway. A metabolic pathway is a series of chemical reactions that are necessary for the survival of a plant. Herbicide-tolerant plants can bypass the blocked portion of the metabolic pathway. This ability comes from genes that produce certain enzymes that provide a different chemical route around the blocked portion. An example of a herbicide-tolerant crop is Roundup Ready™ soybeans from Monsanto. These plants can tolerate glyphosate, the active ingredient in the herbicide. Glyphosate blocks a section of the metabolic pathway, which kills most types of plants. Researchers discovered that a common bacteria found in soil contains a gene that resists glyphosate. They inserted this gene into soybean plants. It produces an enzyme that provides a chemical path around the blocked portion. With this new gene, the soybean plants are not noticeably affected by Roundup™ or any glyphosate herbicide.

How Insect-Resistant Plants Function

A common soil bacterium called *Bacillus thuringiensis (Bt)* was first identified in 1911. Different strains of the bacteria produce a protein that kills some types of insects. When ingested it dissolves the wall of the insect's gut, which causes the insect to be unable to eat and eventually to die. *Bt* was registered as a biopesticide in 1961. However, the pesticide produced from the bacteria had several drawbacks; it was expensive, had to be eaten by insects to work, broke down in sunlight, and was easily washed away by rain. These factors have limited the use of *Bt*-derived pesticides.

Each *Bt* strain kills a specific type of insect. The genes that cause the production of the protein in specific *Bt* strains have been isolated and transferred to several crop plants. For example, Monsanto has developed potatoes, corn, and cotton plants that incorporate *Bt* to protect them against particular insects.

The uses of the *Bt* gene are limited because not all insects are affected by one of the strains of *Bt*. In addition, some people are concerned that insects will become tolerant of the protein produced by the

Bt gene. If this happens, crops incorporating *Bt* will lose their advantage.

How Disease-Resistant Plants Function

Researchers have developed virus-resistant plants by inserting a small portion of DNA from the virus into the DNA of the plant. This modification gives the plant an immunity to the disease. The Freedom II™ yellow crookneck squash developed by Asgrow is an example of a virus-resistant plant. It resists two types of the mosaic virus.

The development of bacteria- and fungus-resistant plants has not been as easy or as fast as the development of virus-resistant plants. Current research in this area centers on trying to enhance the plant's natural immune response to attacks by bacteria and fungi. Some plants seem able to withstand them better than others. Scientists are trying to find out how these plants work so that they can genetically modify crop plants to have this ability. Bacteria- and fungus-resistant plants are not currently available, nor are they expected to be for several years.

The Effect of Biotechnology on Food Quality and Processing

Biotechnology has been used to enhance food quality and food processing. One of the first genetically engineered plants was the FlavrSavr™ tomato. The tomato was developed by Calgene, a subsidiary of Monsanto, to have a vine-ripened taste and a longer shelf life. Genes were inserted into the tomato plant to delay the softening of the tomato by causing the production of an enzyme that slows the breakdown of pectin in the tomato. Pectin prevents the tomato from getting soft and rotting. Four other companies have gained approval for similar genetically modified tomatoes.

Genetically modified canola and corn plants have also been developed. Both corn and canola plants have been genetically modified to produce grains that are higher in oil content and have a modified oil composition. This means that the levels of saturated and unsaturated oil from these plants have been changed to meet different uses. An example of this type of product is a canola plant from Calgene named Laurical® that produces seeds high in lauric acid. The oil they produce can be used in processing many food products.

Monsanto is working on high-starch potatoes. These potatoes are higher in starch and lower in water content than unmodified potatoes. When the new potatoes are sliced into chips or french fries and deep fried, they will absorb less oil. They will therefore have a lower fat content.

Summary

The genetic engineering of plants has yielded better quality foods and plants that are herbicide tolerant, insect resistant, and disease resistant. The development of these plants involves the location, isolation, cloning, and transferral of the desired genes.

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Lesson 4:
Emerging Applications of Plant Biotechnology

The field of plant biotechnology is one of the most rapidly developing areas of biotechnology. The pace of growth is due to several factors, but the most important reasons are the potential for high profits and the relative simplicity of plant manipulation through recombinant DNA technology. As plant biotechnology continues to advance, the list of products developed through its application will grow. Some of these products are examined in this lesson. Biofuels and biopolymers, for example, are two of the most promising products currently under development. The needs of the plant products industry will influence the future of plant biotechnology.

Biofuels

Biofuels are combustible substances derived from organic sources. Nearly all biofuels are plant-derived. Several types of biofuels exist. Alcohol-based fuels are made by fermenting plant materials. Gasohol is one example; it is a fuel composed of 10 percent alcohol and 90 percent gasoline. Gasohol with a 10 percent ethanol (a type of alcohol) blend is available to motorists in many gas stations across the country. Normally, the ethanol blend is slightly higher in price than the regular petroleum fuel. Researchers are searching for plants that can be modified to produce ethanol more economically.

Plant oil-based fuels, or biodiesels, are made from seeds with a high oil content. Most of these fuels are the result of the addition of methanol (wood alcohol) to the plant oil and the removal of a sticky substance called glycerine. Soybean and rapeseed oils are most commonly used in the production of biodiesel. Biodiesel can be used as a fuel by itself, or it can be blended with petroleum diesel fuel. It is a cleaner-burning fuel that produces less wear on an engine than petroleum diesel. The challenge facing those seeking to increase the use of biodiesel is its cost, which is currently nearly four times the cost of petroleum diesel. Scientists are looking for ways to engineer plants to produce larger quantities of oil and to require less extensive processing to produce biodiesel.

Another type of biofuel is biogas. Methane gas is a byproduct derived from the anaerobic (oxygen-free) digestion of plant materials and/or animal waste by microorganisms. Many people in India and China use small-scale methane production chambers to supply fuel for cooking and lighting. Although methane gas has some limitations as a fuel because it cannot be easily transported or compressed into a liquid, researchers are examining the possibility of developing plants that would produce crop residue that is more useful for methane production. Microorganisms are also being examined to see if they can be modified to better digest crop residues and produce more methane.

Biopolymers

Biopolymers are complex chemical compounds produced by living things. Biopolymers from genetically engineered plants may be useful in a variety of industries. Several different groups of biopolymers are used for a variety of applications.

Carbohydrates are one group of biopolymers. All plants produce carbohydrates, but not all plants are a good source of food-grade carbohydrates. Modified corn starch is one of the plant carbohydrates most widely used in foods because it is a cheap source of starch. However, it breaks down when heated in a microwave oven. Researchers are looking at ways that the corn plant can be modified to produce a starch that can be heated. Another important carbohydrate molecule is sugar. Scientists are researching the possibility of genetically altering potato plants so that their leaves will have a high sugar content. The plants could then be used as a source of sugar.

Fatty acids are a second type of biopolymer. Researchers are working on modifying corn and canola to produce oils with an altered level of fatty acids. They may contain a high level of either saturated or unsaturated fatty acids, depending on which is needed for a given application.

Another kind of biopolymer is high-value pharmaceutical proteins. Two examples of human health products that are proteins are insulin and blood plasma. Plants provide the potential for such proteins to be produced at a lower cost than currently available.

A fourth group of biopolymers is industrial enzymes. Enzymes are needed for brewing to aid in fermentation, in the paper industry to process and bleach paper, and in the livestock industry as a feed additive to aid in digestion in animals. These types

of enzymes are needed in large quantities, and scientists are trying to modify plants to provide these enzymes at a low price.

Another type of biopolymer being researched is bioplastics. Plants naturally have a very small amount of the chemical components of plastic in their tissue. Scientists are attempting to develop plants with tissue that contains a much higher level of these components. Researchers have already engineered plants to increase these levels; the chemicals make up 4 percent of the modified plants. If this percentage can be increased, the world will have an expanded source of biodegradable plastics.

Plant Traits Desired by Producers

The ability to genetically engineer plants has caused plant breeders and researchers to stop asking what traits are available in a plant species and to start asking what traits are needed or desired by producers and which plant can best be modified to fulfill this need. As genes for more and more traits are discovered, the possible genetic combinations grow as well. Researchers are focusing on several major areas. One of these areas is that of environmentally tolerant plants, including the development of plants that are drought-tolerant, frost-tolerant, and salt-tolerant. The development of better forestry products is another area of plant research. Traits desired in this area include stronger wood, fire-resistant wood, and trees that grow more quickly. A third area of research involves the development of food products with an improved taste. Products being investigated include sweet corn and peas that stay sweet longer and naturally decaffeinated coffee. Research into fiber crops is being conducted as well. Scientists are trying to produce naturally colored and fade-resistant cotton. Naturally blue cotton that resists fading would create a revolution in the denim industry.

Summary

The rapidly expanding field of plant biotechnology is the focus of a great deal of interest. Biofuels and biopolymers are two examples of the emerging applications of plant biotechnology. Scientists are examining many plants, animals, and microorganisms as a part of their attempts to enhance the traits of crop plants and increase their usefulness.

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Lesson 5:
The Impact of Plant Biotechnology

Many biotechnology products recently released on the commercial agricultural market have been genetically modified plants. *Bt* corn, *Bt* cotton, Roundup Ready™ soybeans, and modified canola are a few examples. The effect of these products and of plant biotechnology is only beginning to be realized. This lesson will explore the impact that plant biotechnology is having on the creation of jobs, economics, human health, and society.

Career Opportunities in Plant Biotechnology

Plant biotechnology offers many of the same career opportunities as those listed in Unit 5 for animal biotechnology. General career areas in biotechnology are research and development, quality control, clinical research, manufacturing and production, regulatory affairs, information systems, marketing and sales, and administration. However, some career positions are unique to the field of plant biotechnology. Plant scientists, greenhouse managers, and tissue culture technicians are a few examples. A bachelor of science degree in agronomy or biochemistry provides a good starting point for a career in plant biotechnology.

Economic Factors Affecting Producers

The true test of any technology is its feasibility and profitability. Developments in plant biotechnology must be financially beneficial for producers if the products are to succeed. Whether it is insect-resistant corn or herbicide-tolerant soybeans, the plant crop developed must be able to increase producer profits. The producer needs to be confident that the price charged for these genetically modified seeds will be recovered, along with a greater profit than that obtained with traditional plant crops.

Modified crops present both benefits and drawbacks for producers. Most of the genetically altered crops currently in use have been modified to resist insects, disease, or herbicides. These crops lower input costs by reducing the amount of chemicals needed to grow them. However, the seed for genetically modified crops is generally higher in price. In addition, several modified crops that producers are beginning to use yield a seed with a modified composition that must be kept separate from unmodified crops when they are harvested, transported, stored, and processed to avoid using them for the wrong application. Crops with a modified composition also must be sold to specific processors. The advantage to these specialized crops is that they are often sold at a premium price, which should offset the costs of handling them and the limited market. These additional risks to the producer require that the modified crop have a higher profit potential. If the profit potential is great enough, producers will readily accept these new crops.

Consumer Health and Safety Concerns

The public has shown much more confidence in the safety of plant biotechnology than in animal biotechnology. Consumers have some health concerns about genetically modified foods. Questions about the healthiness of modified foods arise with foods in which the composition of the edible portion of the plant has changed. The FDA has helped to ease some of these concerns by requiring that foods in which the composition of the food has changed be labeled. Some consumers also worry that a plant altered for an industrial purpose will wind up in the food supply; for example, corn genetically modified for ethanol production could be mixed with other corn for corn meal without anyone knowing. Such safety and health concerns held by consumers must be responsibly addressed if plant biotechnology products are to succeed.

The Global Social Impacts of Plant Biotechnology

Both positive and negative global impacts are associated with the introduction of plant biotechnologies. Some transgenic plants can greatly benefit developing countries, such as the sweet potato resistant to the feathery mottle virus (FMV) developed with support from Monsanto and the U.S. Agency for International Development (USAID). This FMV-resistant sweet potato could nearly double the potato harvest in Africa, where sweet potatoes are grown as a staple crop, and farmers could provide more food for their families. The development of environmentally tolerant plants could help reduce the risk of famine caused by drought or flooding in some countries. Even more exciting is the possibility of developing edible plant vaccines, which would allow millions of poor people to receive vaccines.

However, the development of some genetically modified crops can destroy the profitability of agricultural cash crops that may be vital to a country's economy. For example, the new genetically modified canola seed has the same fatty acid content as many of the tropical oils, such as palm and coconut oils. Producers in the United States and Canada could raise a crop of canola cheaper than these oils could be imported. Many countries have depended on tropical oils for most of their national income, and their economies could be severely hurt if the modified canola is grown. Also, if potatoes, tobacco, and other plants are genetically modified to produce a high amount of sugar in their leaves, the price for sugar from sugar cane will drop, causing problems for growers worldwide. These changes have both an economic and social impact on the countries affected. Will the net effect of plant biotechnology be positive for most countries? Only time will reveal the answer to this question.

Summary

The field of plant biotechnology is growing quickly. Many different types of career opportunities exist in this field. As more genetically modified plants are developed and offered to producers, the ability of producers to measure the economic risks and profit potential of these crops will be vitally important. Consumer concerns about the safety and healthiness of foods made from modified plants must be addressed. The global social impact of each modified plant must also be examined to help minimize negative results.

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GLOSSARY

A

adenine - One of the four nitrogen bases found in the nucleotides making up DNA.

allele - Either of the two possible expressions of a gene or multiple genes that code for a specific trait, usually represented by a letter of the alphabet. If the gene acts as a dominant gene, a capital letter is used to represent it; a lowercase letter is used to represent a recessive gene.

anaphase - 1. Third stage of mitosis, in which the chromatids of the chromosomal unit are pulled apart and move toward opposite poles of the cell. 2. The third stage of the first phase of meiosis, in which homologous chromosomes separate and are pulled to different poles (anaphase I). 3. The third stage of the second phase of meiosis, in which chromatids separate and move toward opposite poles (anaphase II).

antibodies - Proteins produced in response to an antigen.

antigen - A substance that triggers an immune response, or the production of antibodies.

artificial insemination - Process of collecting semen from a male animal and placing it into the reproductive tract of a female animal.

artificial vagina - A device consisting of a water-filled plastic sheath with a collection tube in one end that holds semen after ejaculation; it is found within a dummy that male animals are trained to mount.

aseptic technique - Procedures used to create and maintain a working area that is free of bacteria and other microorganisms that might contaminate delicate experiments.

autoclave - A piece of laboratory equipment using steam under high pressure to sterilize glassware, plastic ware, etc.

B

benefit-to-cost ratio - A ratio calculated by comparing the economic benefits of using a product to the costs of using the product.

biodiesel - Fuel based on plant oils extracted from seeds with a high oil content.

biodiversity - The diversity in the numbers of different species of plants and animals.

biofuel - Combustible substance derived from organic sources; nearly all biofuels are derived from plants.

biopolymer - A complex chemical compound produced by living things.

biotechnology - The application of scientific principles to living things; "bio" refers to living things, and "technology" involves the application of science. It involves harnessing the natural biological processes of cells from microorganisms, animals, and plants to develop useful products. Modern biotechnology includes processes that involve the recombination of genes from living things in a laboratory setting.

C

callus - An area of rapidly dividing cells that forms and grows on a plant tissue in response to wounding or cutting.

cell division - Process in which the material in a cell is divided to produce two new cells, either by meiosis or mitosis.

cell membrane - Structure that forms the boundary of an animal cell and controls the movement of substances into and out of the cell. In plants, the cell membrane is located just inside the cell wall. It is also called the *plasma membrane*.

cell plate - A structure that forms in a plant cell during telophase and divides it into two cells. It eventually becomes a cell wall.

cell wall - The rigid outside layer of a plant cell that provides support for the cell and works collectively with other cells to support the plant; it has openings that allow substances to pass through the cell wall.

centriole - A structure that serves as an anchor for the network of microtubules formed during meiosis and mitosis.

centromere - Body that holds two strands of a chromosomal structure together.

chloroplast - Plant organelle containing chlorophyll used in photosynthesis.

chromatid - An individual strand of the double-stranded chromosomal structure seen in mitosis and meiosis.

chromosome - Tightly wrapped pieces of DNA that function as a unit; the location of genes.

cloning - The asexual reproduction of an organism in which the resulting organisms are identical.

coarse adjustment - Large dial of a microscope used to focus the low-power objective.

codon - Sections of DNA three nucleotides long that code for one of the twenty amino acids.

collection cylinder - A container that holds the flushing solution and embryos after they have been removed from the donor during embryo transfer.

condenser - The part of the microscope that focuses light from the lamp onto the specimen.

crossing over - A random exchange of segments between nonpaired chromatids in a tetrad during the prophase stage of meiosis.

cytoplasm - The contents of the cell, excluding the nucleus; it includes many structures, called organelles, that fill different roles.

cytosine - One of the four nitrogen bases found in the nucleotides making up DNA.

D

design patent - A patent granted for any new, original, and ornamental design for a manufactured article.

diploid - Containing two complete sets of chromosomes; found in somatic cells.

disc diaphragm - The part of a microscope that contains a series of openings of different sizes that control the amount of light shining on the specimen.

DNA (deoxyribonucleic acid) - The genetic material of the cell composed of small chemical units call nucleotides, which consist of three parts: a phosphate group, a sugar (deoxyribose) unit, and one of four nitrogen base units (adenine, guanine, thymine, and cytosine).

DNA fingerprinting - The process of using the laboratory analysis of DNA to generate a pattern that is unique to an individual organism and can be used for identification; it involves fragmenting DNA with a restriction enzyme and then segregating the fragments with gel electrophoresis to produce a distinct pattern.

DNA replication - Process in which DNA copies itself using a strand of DNA as a template.

dominant gene - Gene that is expressed; it masks the expression of a recessive gene.

double helix - The structure of DNA, which looks like a twisted or spiraling ladder; it consists of two intertwined strands of nucleic acid, with the phosphate and sugar units of nucleotides forming the sides of the ladder and nitrogen base units joined by hydrogen bonds forming the rungs.

E

electrophoresis unit - A piece of laboratory equipment that uses an electric current to separate DNA fragments by size.

embryo flushing - A process that uses fluid to remove embryos from a donor female's reproductive tract.

embryo splitting - A method of cloning that involves physically splitting an embryo into two halves as it is dividing; each half is transferred to a recipient and develops into a normal offspring.

embryo straw - A plastic straw that holds an embryo for transfer.

embryo transfer - The process of transplanting embryos from a donor female animal to a recipient female animal.

embryo transfer gun - A piece of equipment used to expel the embryo into the reproductive tract during embryo transfer.

endoplasmic reticulum - A large network of membranes that transports materials within the cell; the location of the ribosomes.

explant - In plant tissue culture, the portion of the parent plant that will be used to grow new plants. It may be a shoot tip, bud, section of a leaf with veins, node, or bud scale.

F

fine adjustment - Small dial of a microscope used to refine the focus or to focus the high power objective.

fume hood - Laboratory equipment that vents air and fumes to the outside.

G

gamete - A sex cell, either an ovum or a sperm cell.

gel electrophoresis - A procedure in which an electric current is applied to a gel to separate different lengths of DNA fragments into groups. It can be used for DNA fingerprinting or to recover a desired gene or gene fragment.

gene - A segment of DNA on a chromosome that produces a polypeptide (protein). Genes are responsible for the expression of genetic traits because the proteins produced by genes control the appearance, growth, and function of the organism.

gene gun - A small high-pressure gun capable of penetrating the walls of a plant cell using very small, heavy metal pellets; it is used to transfer a desired gene into a plant cell.

gene mapping - The process of finding the location of genes on the chromosomes of an organism.

gene sequencing - A process related to gene mapping that shows the order of all the base units (A, T, C, G) as they line up on a particular gene.

gene-splicing - The process of inserting a piece of DNA into a chromosome of a cell to produce recombinant DNA. It is also referred to as litigation because the enzyme ligase is the biochemical glue that joins the pieces of DNA.

genetic engineering - The alteration of the genetic material of living cells by incorporating different genes to produce organisms with new characteristics.

genotype - The specific combination of the alleles a plant or animal possesses for each individual genetic trait; the actual genetic makeup of the organism.

Golgi apparatus - A cell organelle that works with the endoplasmic reticulum in transporting proteins by packaging protein molecules for movement within and outside of the cell.

growth chamber - A room used for plant tissue culture that allows heat and light exposure to be controlled.

guanine - One of the four nitrogen bases found in the nucleotides making up DNA.

H

haploid - Containing a single set of chromosomes; found in gametes.

heterozygous - Having one dominant allele and one recessive allele for a trait.

histone - A protein molecule around which DNA is wrapped.

homologous chromosomes - Paired chromosomes that contain the same set of genes, one from each parent of an organism.

homozygous - Having two dominant alleles or two recessive alleles for a specific trait.

hypothesis - A focused and detailed statement that can be tested for accuracy and anticipates the outcome of an experiment; it directs the methods of experimentation.

I

incubator - A piece of laboratory equipment used for tissue culture and the propagation of bacteria; it maintains a preset temperature that provides an optimum climate for cell cultures to grow.

insemination instrument - A syringe-like tool that holds the semen straw and deposits the semen into the female animal's reproductive tract during artificial insemination.

in vitro fertilization - The process in which immature follicles (ova) are collected from the ovaries of a female animal, stimulated to mature, and fertilized outside the female reproductive tract in a test tube and are then transferred to recipient animals.

L

laboratory notebook - A bound notebook that provides a detailed record of the day-to-day activities of an experimental process.

laboratory sheet - One of the pages within a laboratory notebook that is used to record information from individual experiments.

ligase - An enzyme used to join pieces of DNA in gene-splicing.

M

Material Safety Data Sheet (MSDS) - A sheet of safety information that must accompany all chemicals and provides a variety of information about a chemical, including its toxicity level, first-aid measures, required personal protective equipment, and disposal procedures.

meiosis - A type of cell division that produces gametes, which contain half the number of chromosomes found in the parent cell.

metaphase - 1. The second stage of mitosis, in which the chromosomal units move to the center of the cell, forming a line between the two poles of the cell, and are attached to the spindle fibers. 2. The second stage of the first phase of meiosis, in which homologous chromosomes line up in the center of the cell and spindle fibers attach to the centromeres (metaphase I). 3. The second stage of the second phase of meiosis, in which chromosomal units line up in a row between the two poles and become attached to the spindle fibers (metaphase II).

microcentrifuge - A piece of laboratory equipment that separates solids from a liquid.

microscope - A piece of laboratory equipment for enlarging and viewing organisms or specimens that are not visible to the naked eye so that they can be observed.

microtubule - A complex protein unit shaped like a hollow tube that helps form the spindle in mitosis and meiosis.

mitochondria - Organelles that are the powerhouses of the cell; they break down nutrients to provide energy.

mitosis - A type of cell division in which somatic cells divide to form two new cells, each of which contains the same number of chromosomes as the parent cell, or a diploid number of chromosomes.

monoclonal antibodies - Antibodies produced by fusing a tumor cell to an immune system cell that produces antibodies against a specific antigen. It yields a cell that divides rapidly and produces the desired antibody.

motility - A term used in artificial insemination when describing the active movement of sperm.

mutation - An alteration of the nucleotide sequence found in a DNA molecule.

N

nuclear transfer - A method of cloning that involves removing the nucleus of an unfertilized ovum, extracting a cell from a parent organism, and fusing it into the ovum without a nucleus using an electrical pulse.

nucleotide - A small chemical unit that makes up the structure of DNA; it consists of a phosphate group, a sugar unit (deoxyribose), and a nitrogen base, either adenine (A), guanine (G), thymine (T), or cytosine (C).

nucleus - The control center of a cell, contained within a pair of nuclear membranes.

O

objective - The second lens system of a microscope that magnifies the image and projects it up to the ocular.

ocular - The eyepiece, or initial viewing point of a microscope, that contains the first lens system and usually magnifies the image to 10 times.

organelles - Structures found in cells that perform specialized functions.

P

patent - Property rights granted by the U.S. Patent Office that exclude others from making, using, or selling a patented invention throughout the United States for a stated period of time, normally 17 years.

pathogenic - Capable of causing disease.

PCR equipment - Laboratory equipment, such as hot water baths or a thermocycler, used to cause the replication of DNA.

phenotype - The appearance or expression of a trait as determined by the genotype.

pipettor - A piece of laboratory equipment used to measure and transfer amounts of liquid smaller than one milliliter (ml).

plant patent - Patent issued to anyone who invents or discovers and asexually reproduces any new variety of plant, including cultivated spores, mutants, hybrids, and newly found seedlings.

plant tissue culture - An asexual method of reproduction in which a piece of a parent plant is placed in a sterile artificial media and grown into a new plant. The plant produced will be an exact clone of the parent plant.

plasmid - A small circular piece of DNA that codes for specific traits and replicates independently of the chromosomal DNA.

problem statement - A statement that expresses the general purpose of research and states the problem in such a way that it will lead to experimentation that will solve the problem.

prophase - 1. The first stage of mitosis, in which chromosomes coil and condense into double-stranded structures, the nuclear membrane dissolves, and microtubules begin to form a spindle extending toward the center of the cell. 2. The first stage of the first phase of mitosis, in which homologous chromosomes pair together, the nuclear membrane dissolves, and a spindle forms (prophase I). 3. The first stage of the second phase of meiosis, in which paired chromatids move to the center of the cell and spindle fibers develop (prophase II).

protease - Enzyme used to split protein molecules to allow DNA to be extracted.

R

recessive gene - Gene that is not expressed, or apparent in the traits of an animal.

recombinant DNA - DNA spliced together from two different sources, forming a new genetic code.

restriction digestion - A process in which DNA is cut into smaller fragments with restriction enzymes. Each restriction enzyme cuts DNA at a different sequence of base pairs.

restriction enzyme - Enzyme that cuts DNA at a specific sequence of nucleotide base pairs.

restriction site - A specific sequence of DNA base pairs that are cut during restriction digestion using a restriction enzyme.

ribosome - Cell site where protein molecules are assembled, or synthesized.

S

scientific method - A rational and structured system for researching scientific questions that involves the formation of a hypothesis and data collection through experimentation.

semen straw - A long, thin plastic tube that contains the correct amount of semen for breeding one female animal using artificial insemination.

semen tank - A storage container containing liquid nitrogen that is used to store semen straws.

somatic cell - Any of the cells in an organism except the sex cells, or gametes.

spill pillow - A piece of laboratory safety equipment used to absorb spilled liquid chemicals.

spindle - Network of microtubules that separates homologous chromosomes and/or chromatids during mitosis and meiosis.

stylet - A device used to insert a catheter into the vagina and through the cervix for embryo transfer.

superovulation - The release of multiple ova caused by injecting a donor female animal with a hormone.

supplemental hormones - Chemical messengers administered to animals to stimulate them to grow, produce more milk, or improve their performance in another way.

T

telophase - 1. The last phase of mitosis, in which the cell membrane and cell plate (in plant cells) close off the two new cells, nuclear membranes develop, and chromosomes uncoil. 2. The last stage of the first phase of meiosis, in which the cell plate and/or cell membrane and nuclear membranes form (telophase I). 3. The last stage of the second phase of meiosis, in which the cell plate and/or cell membrane and nuclei form and chromosomes uncoil.

tetrad - A grouping of four chromatids from a pair of homologous chromosomes that occurs during prophase I of meiosis.

therapeutic proteins - Substances produced by genetically modified bacteria that when injected into an animal attack viruses and stimulate an animal's immune system to attack viruses.

thiamine - One of the four nitrogen bases found in the nucleotides making up DNA.

transgenic - Incorporating genes from some other source.

transilluminator - A piece of laboratory equipment used to view an electrophoresis gel by passing a shortwave ultraviolet light through it.

U

utility patent - A patent granted for "new and useful" inventions that meet certain statutory requirements; the most common type of patent granted to biotechnology products.

V

vacuole - Storage unit of the cell; it may store water, enzymes, pigments, and other substances.

vortex - A piece of laboratory equipment that mixes a solid with a liquid in test tubes.